Summer 2018

RC Baja Car Drivetrain/Steering Assembly

Douglas Erickson
Central Washington University, douglas.erickson@cwu.edu

RC Baja Car Drivetrain/Steering Assembly

By

Douglas Erickson

Partner: Torrie Large

Table of Contents

1: INTRODUCTION

Description:

Each year ASME hosts a design challenge focusing on different components of a simple RC car and how it performs under different challenging courses. This will challenge the design, manufacturing, and testing ability of engineering.

Motivation:

The motivation for this project stemmed from the necessity of an RC Baja car that can compete at the ASME RC Baja Competition at a competitive level.

Function Statement:

The function of the drive train is to deliver the power from the provided electric motor to the axle or the wheels directly to propel the vehicle. The function of the steering assembly is to change the direction of the vehicle’s movement while the vehicle is moving.

Requirements:

The car must satisfy the following requirements as well as the ASME RC Baja Race requirements.

- The RC Baja car must be able to compete in all of the RC Baja Competition events (slalom, sprint, and off-road)
- The drivetrain must be able to withstand the high RPM of the motor (40000 RPM) and reduce it to 1500 RPM
- The drivetrain must facilitate a gear reduction of approximately 13:1.
- The car must reach a top speed of 20 mph.
- The drivetrain will fit within the size (50 x 50 x 50 cm) requirements of the competition as well as be able to fit on the chassis of the car.
- The steering assembly must allow the RC car to have a turning radius of less than 2 feet
- The steering assembly will not weigh over .67 pounds.

Success Criteria:

The success of the project is determined by the vehicles ability to perform at a competitive level the RC Baja competition with in the restraints placed by the event holders.

Scope:

This part of the project will only cover the drivetrain and steering mechanisms of the vehicle. The drivetrain includes the transmission and differential. The remainder of the project will be covered by Torrie Large.

Design & Analysis

Initially when designing the drivetrain, the axle was to be driven via belt directly from the transmission to the rear axle. This design presented advantages of simplicity and lightweight due to its limited number of parts. This design however did not allow for simple integration of a differential. Since the differential is crucial to the performance of the vehicle during the slalom event, a gear driven drivetrain is ultimately chosen.

The gear driven transmission and differential maintained the need for simplicity and lightweight by excluding a driveshaft and mounting the transmission directly to the differential. This adaptation allowed for a lighter overall drivetrain as well as a better allocation of space. Since the vehicle is rear wheel driven, the consolidation of the drivetrain allocated more weight to the rear of the vehicle, thus increasing the traction of the rear wheels.

To satisfy the requirements of the project a R.A.D.D. approach was implemented. A quintessential CWU method, R.A.D.D encorporates engineering standards by first defining a requirement, performing analysis to meet the corresponding requirements, and subsequently designing and drawing a parameter that appeases the analysis.

The first requirement to be satisfied is the top speed requirement of 20 mph. The analysis for this is done by first calculating the axle rotational speed corresponding to 20 mph using the intended tire circumference and unit conversions. The overall drivetrain gear ratio is then calculated by dividing the maximum rated motor rotational speed (RPM) by the axle speed. The value for the differential gear ratio is determined using a recommended value from previous experiments. To determine the transmission gear ratio the differential drive ratio is factored out of the overall drivetrain ratio. With a standardized gear pitch and the gear reduction, the gear and pinion teeth numbers can be determined. The resulting design parameter of this analysis is a transmission gear ratio of 5.2:1 with a 10-tooth pinion and a 52-tooth gear. (Appendix A.1)

Subsequent to determining gear ratios is the design of the gears and their associated values. The outer diameter for the pinion is calculated using the pitch and number of teeth. The rotational speed of the pinion is used to calculate the angular velocity. The tangential velocity is then calculated by multiplying the angular velocity by the radius of the gear. These same calculations are performed identically for the gear. (Appendix A.2)

The major requirement placed on the steering assembly is to allow the vehicle a turning radius of less than 500mm (1.6ft). The overall length of the vehicle is determined initially by the space required from the components on the vehicle. Using the Ackermann steering geometry, the length and width are used to calculate the angle of the steering arm. This steering principle provides non-slip steering which in turn reduces wear on tires. The resulting angle is used in the Ackerman radius equation to calculate the current radius. While the current length of the vehicle allows for a turning radius of under 500mm, failure to do so would result in redesign of the overall chassis length and width. (Appendix A.8)

A major change that was implemented during the construction phase of the project was the separation of the differential housing from one to two parts. Having the differential housing designed as a singular one-part component placed serious challenges when assembling the inner gears and mounts to the differential. This analysis of how the differential was housed placed a design requirement on the housing that it had to facilitate the easy and possible assembly of the differential. The differential was split into two halves with slots that interlock when they are placed together. To facilitate this change, the differential cover design was changed also to include an exterior set of walls with cutouts where the shafts enter and exit the housing (Appendix B.4). With the walls on the cover, the differential can be assembled and the two halves are held together suitably.

Another design change that was implemented during the construction of the drivetrain was the shape of the pinion gear that mates with the large differential gear. When first constructing the vehicle it was assumed that the friction force of the set screw was enough to withstand the torque of the motor. This assumption did not take into account the increase in torque from the gear reduction of the transmission. To take this into account, a flat is milled into the shaft so that the set screw mates fully with the shaft.

Predictions:

Based on the current gear reductions the top speed of the vehicle is predicted to reach 20 mph at full throttle. The vehicle is predicted to make a 180 degree turn within 437mm with the current chassis dimensions and inclusion of a differential.

Methods and Construction

The idea for this project was conceived from the two group members involved at the CWU campus. The analysis, design, manufacturing, and testing are also completed within the restraints of the CWU campus build and design facilities.

Drivetrain

The drivetrain consists of four major components that are fabricated using the available equipment at the CWU MET department. The remaining parts for the drivetrain are purchased from a third party and will be used in relation with the machined parts. These parts consist of all gears, bearings, pins, and washers associated with the drive train.

The drivetrain is a compact design in which the motor transmission directly interacts with the differential. The first component of this design houses the motor, gear, and pinion of the transmission in a linear fashion with all of them in a row as can be seen Appendix B.1. Directly across from this component, the differential is mounted with the input directly in line with the gear of the transmission. A short shaft is mounted from the transmission gear to the differential pinion. The differential housing (Appendix B.2) houses the drive gear and pinion, bevel gears, and bearings for the differential. This component directly mounts to the frame of the vehicle through the screw cutouts in the base. The pinion of differential mates with the master gear at a 90-degree angle. The differential case (Appendix B.5) mounts directly to the master gear and houses the four bevel gears of the differential. The mating setup (Appendix B.6) has two bevel gears mounted perpendicular to the axis of rotation in opposition and two gears parallel to the axis of rotation. The two gears parallel to the axis are mounted to drive cups (Appendix B.11) which connect to the CVD axles (Appendix B.7). The drive cups are held in place by bearings which are adhered to the hole cutouts of the differential housing. To avoid the interference of dirt, wires, and other miscellaneous objects, the differential is covered by the differential cover (Appendix B.4). The differential cover mates directly with the differential and also holds together the differential housing halves. Not only does this protect the gears from debris but also provides stability for the mating of gears. Assembly can be seen in Appendix B.8.

The motor mount/transmission as well as the main differential components are manufactured of abs thermoplastic using a 3D printing process. The parts are modeled in SolidWorks in accordance with the restraints placed by the printer. This process was chosen due to the complex geometry of the part as well as the size making it difficult to machine. For the sake of accuracy, the existing parts are measured using precision measurement equipment and modeled in solid works. With the purchased parts in solid works, the design and troubleshooting process involved with the made parts is easier. The printing process begins with the completed design model that is converted to a .stl file. The .stl file is sent to the printer where it is printed in roughly 1-5 hours. After the parts have been printed, they still rely on a second process to remove the support material. For 2-4 hours the parts are placed in a heated bath of lye acid that is agitated to remove the support material.

This process provides accurate prototypes in a short period of time that can be implemented immediately into the assembly. The downside of this method of construction is that the precision of layer plastic molding is barely adequate for the smaller components of the assembly. This problem is easily remedied by enlarging the certain parts of each component that mates with another. The parts will not mate immediately after construction but can be easily modified using reamers and files. This also made the process of force fitting the bearings relatively easy since the holes only needed to be reamed to the nominal design size. For the entrance hole to the differential, the fit of the bearing required a different measure due to the fact that the hole is split between the two halves of the housing. Having the hole spit between two halves, make it difficult to have a reliable fit between the bearing and the housing. A different bearing was chosen to include a flange at one end and the housing cover was augmented to allow for the flange. This caused the bearing to be tightly held in place by the differential cover.

Steering Mechanism

The steering assembly (Appendix A.11) consists of a servo motor that mates with a steering rod that is parallel to the axle. The steering rod is offset from the axle using the Ackermann steering principle and interacts with steering arms. The steering arms are angled to provide non-slip turning and not interfere with the axle. The servo motor uses a spindle like wheel to move the steering rod laterally left to right.

The steering rod is machined from 6061 aluminum flat bar stock and machined with the manual mill and drill press. With one hole in the middle of the bar and one on the servo wheel, a pin loosely mates with the two. Having the pin loose, allows for the steering rod to move back and forth without binding.

Testing

Drivetrain

With the majority of the RC car finished, the first design requirement that is tested is the overall top speed of the car when given full power. Pertinent information for testing this parameter include the overall weight and dimensions of the finished product. To directly test the top speed, a specified linear distance of 20 feet is marked on a flat surface. An underlying goal of this test is to determine the maximum acceleration of the vehicle. This is done by measuring the amount of distance needed to reach top speed through a series of different trials. Initially the tests regarding acceleration are done by giving the vehicle maximum power until the vehicle is at full speed. This test requires two people to more accurately determine the distance. The parameter in this case is an auditory analysis of the drivetrain's pitch as it nears its top speed. The drivetrain will produce a tone that increases as a function of the drivetrain speed increasing. With the throttle being initialized at 100% for this test there is slippage that occurs within the gears and the contact between the tires and the ground surface. The mitigate this a more efficient method of acceleration is tested for by instead increasing the power to the motor more slowly. This can take many trials until an ideal acceleration is determined. The RC Baja experienced a large amount of slippage from tires as well as on the shaft of the transmission resulting as a result of the motor given full power initially. After several trials the ideal acceleration was determined by gradually increasing the throttle position until about halfway, and then immediately increasing the throttle to full power.

One major factor that changes the variability of the test is determining the surface that the vehicle drives on. When initially testing the vehicle, a large amount of slippage from the tires occurred when testing in the Fluke lab, which has a smooth, polished, stone surface. Testing the acceleration on this surface led to the distance from rest to full speed being between 30 and 40 feet. This was made better by changing the testing setting to the outside patio of the Hogue tech building. The concrete provided a larger coefficient between the tires and the ground, allowing for more traction. On the concrete surface, the vehicle accelerated from rest to full speed in under 15 feet.

After determining the distance needed for the car to reach top speed, the car is placed that exact distance away from the first 20 foot marker. The car is accelerated to its top speed using the previously determined method. When the car reaches the first marker, a stopwatch begins measuring the time required for the vehicle to reach the second marker. For accuracy two people were needed for the test, one to measure the time and the other to control the vehicle. Several trials of the test were taken for an average result of 7.45 mph. The operator of the vehicle would stand at the starting end of the test area and face directly towards the finish of the test. This would allow the operator to see the path of the vehicle in a straight context. If the vehicle swayed out of alignment from the finish line more than 1 foot, a retrial would take place, since the result wouldn't be accurate. Knowing that speed is distance/time the speed is first measured in ft/s and then converted to mph. These s values were then confirmed using a secondary testing method which included the use of an app called SpeedClock. This app uses the mechanics of a slow motion camera to determine the speed of an object by tracking its position in the frame over time. First the length of the vehicle is input to the app so that it can track accurately. The view of the camera is angled so that it is directly perpendicular to the line of travel of the vehicle. Many trials were conducted using this secondary method of testing to confirm the previously determined speed. This method produced the same results as the aforementioned method with a margin of error of 2.8 percent.

Steering Mechanism

Since one of the primary requirements for the steering mechanism is turning radius, that is the first parameters of the steering mechanism to be tested. This is performed by placing the vehicle at a standstill and marking the center of the rear axle on the floor (Point A). The vehicle is then turned completely to the left or right and given a small amount of power to perform the turn. The vehicle is stopped when the position of the vehicle is exactly 180 degrees from the original position. The center of the axle is marked again (Point B) and the distance is measured from the first point to the second. To test the accuracy of the accuracy of the steering principle, the vehicle is placed on a drawing surface is pushed to perform a turn. The tracks made by the wheels are marked on the paper and the radii are measured. Using the measurements the circles can be observed as being concentric or out or alignment.

Budget

The overall cost of this project is estimated to be just over 100$ for the parts included. This estimate does not include small parts such as bearings and pins, which are estimated to not be more than 20$. A possible risk of keeping a small budget is the material required for multiple alterations of the parts to be fabricated, especially 3-D printed parts. This risk is also true for parts machined from steel but not as big since existing metal parts are more easily altered. The parts for this project are funded by personal funds. A table of the total part cost be observed in Appendix D.1.

Ordering all of the planned parts presented no substantial increase in cost since the majority of major parts were on one order from one proprietor. While the cost of small intermediary parts such as bearings and pins were predicted as being less than 20$ total, they were all ordered from different companies which caused a large relative shipping cost for each part. This brought the total cost of intermediary parts to 52$, well over the projected cost and budget of the project. The cost of the main designed parts was underestimated since they were initially expected to be machined out of metal. Due to the complexity of the parts and the interest of time, the parts were 3-D printed to ABS plastic bringing the cost per cubic inch to 6$. With the total volume of a single print being 3.71 $in.^3$ the total cost to print the drivetrain once is 22.17$. Certain parts of the drivetrain needed to be reprinted several times due to design changes in measurement. Aside from the major changes in design, the remainder of any augmentations to the printed parts were done in the machine shop to minimize cost.

Schedule

This timeline of this project was initially estimated during the design phase before any construction had been done. The time involved for designing the components were accurately estimated as the amount of time estimated usually reflected the time it took and in some cases was overestimated. The main time constraint placed on the design process was assurance that the designed components would mate with the purchased parts. This was a result of having the items shipped at a later date causing the design of certain components to be at a standstill. In addition to taking time to arrive, the measurement of the purchased parts proved to be more time consuming than estimated. Due to the meticulousness of measuring many small parts as well as modeling them in SolidWorks, the actual time required was 10 times the amount estimated.

This setback not only impacted the design process, but it also carried through to the construction phase. The construction process was impacted by the delay of the differential bevel gears being delivered on time. This was caused by a backorder of the parts, and the gears weren't delivered until 2 weeks into the construction phase. The absence of the bevel gears disallowed the differential case (gear mounts) to be designed until they had arrived and been measured. This delay was shortly overcome by the construction method being plastic printing. Once the parts had all been modeled in SolidWorks, the process of manufacturing significantly expedited the entire process. The construction method was able to bring the project back on schedule due to its speed in producing a result. This pace was maintained until the drivetrain was finished and ready to be implemented on the car. The manufacturing of the steering rod did not take place until after the specified date be due to last minute changes in design. The intended front wheel axles were different from the initially chosen pair. This dramatically changed the design of the steering mechanism which subsequently changed parts of the chassis. To ensure that the specifications of the steering rod could be met, the steering rod was manufactured after the rest of the vehicle had been made.

Discussion

The process of this design began with determining method of delivering the power from the electric motor to the wheels in practical manner. To make this as simple as possible the initial design consisted of having a belt run directly from the motor to the axle. This design provided the advantage of simplicity thus decreasing the risk of a potential failure for a component. This also proved to be a more lightweight design as it consisted of significantly less parts therefore increasing acceleration. The problem discovered with this design is that it only favored the acceleration even of the RC Baja competition. Without a differential, the vehicle would experience a large amount of slippage and losses during the slalom event. To remedy the losses of a single rear axle, the belt drive was abandoned and replaced with a gear driven drive train. This initially consisted of a transmission positioned towards the middle/front of the vehicle and a double joint shaft connecting from the transmission to the differential. Upon analysis it was discovered that the preexisting design for the motor housing interfered with the drive shaft and used a fair amount of space on the chassis that could be better allocated. Instead of redesigning the motor mount/transmission, the solution was to abandon the driveshaft entirely. This allowed for the positioning of the motor mount/transmission to be flipped so that the exit gear of the transmission could interact directly with the pinion that leads into the differential. This solution was beneficial in both practicality and allocation of space. Having the motor/mount/transmission closer to the rear axle, gives the rear tires a higher friction force thus increasing traction. Having more traction is beneficial to the acceleration portion of the RC Baja event, more so than having a belt drive.

The design of steering mechanism was greatly influenced by the slalom event requirement where the vehicle's success is determined by its ability to steer. To achieve the most efficient steering setup, the Ackermann steering principle was used to mitigate slipping caused from simple steering mechanisms.

Conclusion

All of the physical requirements placed by the RC Baja competition have been including and especially the vehicles capability of performing all of the events included at competitive level. The design also fits within the size requirements and uses all vetted components. Overall cost of the vehicle is well within a reasonable budget of 150$ for parts and labor. The time constraint placed by the senior project class is also satisfied. The engineering merit has also been satisfied with this vehicle designed to be as efficient as possible. With practicality, cost effectiveness, and time constraints in mind, this design satisfies both the requirements of the senior project class as well as the RC Baja event requirements.

Acknowledgments

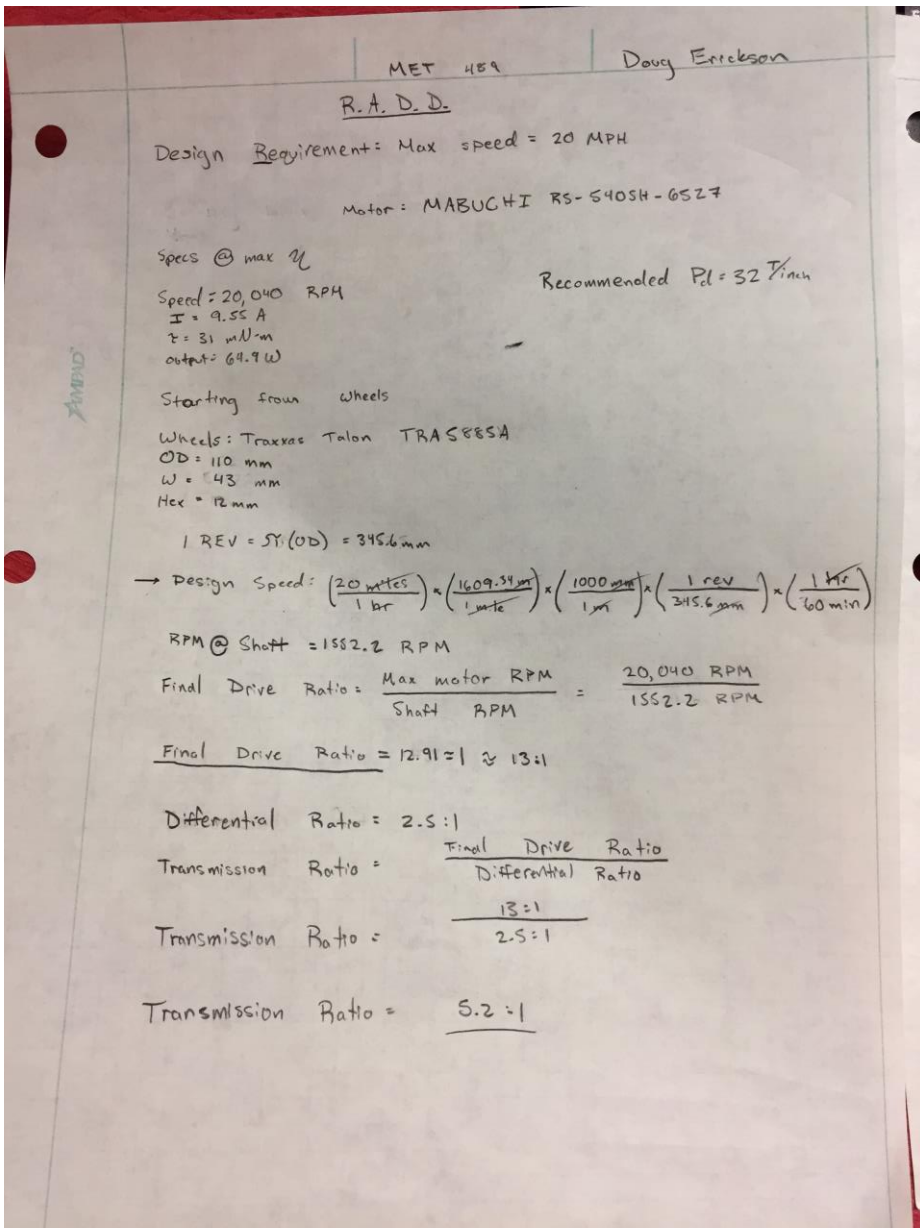
Matt Burvee and Nolan Stockman for their assistance during the manufacturing process. Their combined knowledge of the machine shop and manufacturing helped the progress of this project move fluidly. Roger Beardsley for his contribution of necessary components as well as his expertise with RC Baja.

Mentors:

Roger Beardsley – CWU
Charles Pringle – CWU
Craig Johnson – CWU

Appendix A.1

The first requirement to be satisfied is the top speed requirement of 20 mph. The analysis for this is done by first calculating the axle rotational speed corresponding to 20 mph using the intended tire circumference and unit conversions. The overall drivetrain gear ratio is then calculated by dividing the maximum rated motor rotational speed (RPM) by the axle speed. The value for the differential gear ratio is determined using a recommended value from previous experiments. To determine the transmission gear ratio the differential drive ratio is factored out of the overall drivetrain ratio. With a standardized gear pitch and the gear reduction, the gear and pinion teeth numbers can be determined.



MET 489 Doug Erickson

R.A.D.D.

Design Requirement: Max speed = 20 MPH

Motor: MABUCHI RS-540SH-6527

Specs @ max η

Recommended P_d = 32 T/inch

Speed = 20,040 RPM
I = 9.55 A
τ = 31 mN-m
output = 64.9 W

Starting from wheels

Wheels: Traxxas Talon TRA5885A
OD = 110 mm
W = 43 mm
Hex = 12 mm

1 REV = π(OD) = 345.6 mm

→ Design Speed: $\left(\frac{20\ \cancel{\text{miles}}}{1\ \text{hr}}\right) \times \left(\frac{1609.34\ \cancel{\text{m}}}{1\ \cancel{\text{mile}}}\right) \times \left(\frac{1000\ \cancel{\text{mm}}}{1\ \cancel{\text{m}}}\right) \times \left(\frac{1\ \text{rev}}{345.6\ \cancel{\text{mm}}}\right) \times \left(\frac{1\ \cancel{\text{hr}}}{60\ \text{min}}\right)$

RPM @ Shaft = 1552.2 RPM

Final Drive Ratio = $\frac{\text{Max motor RPM}}{\text{Shaft RPM}} = \frac{20{,}040\ \text{RPM}}{1552.2\ \text{RPM}}$

Final Drive Ratio = 12.91 : 1 ≈ 13:1

Differential Ratio = 2.5 : 1

Transmission Ratio = $\frac{\text{Final Drive Ratio}}{\text{Differential Ratio}}$

Transmission Ratio = $\frac{13:1}{2.5:1}$

Transmission Ratio = 5.2 : 1

Given: - Transmission Ratio
- P_d

Pinion Specs from Part #100

$P_d = 32$
Bore $\frac{1}{8}$ inch
$N_p = 10$

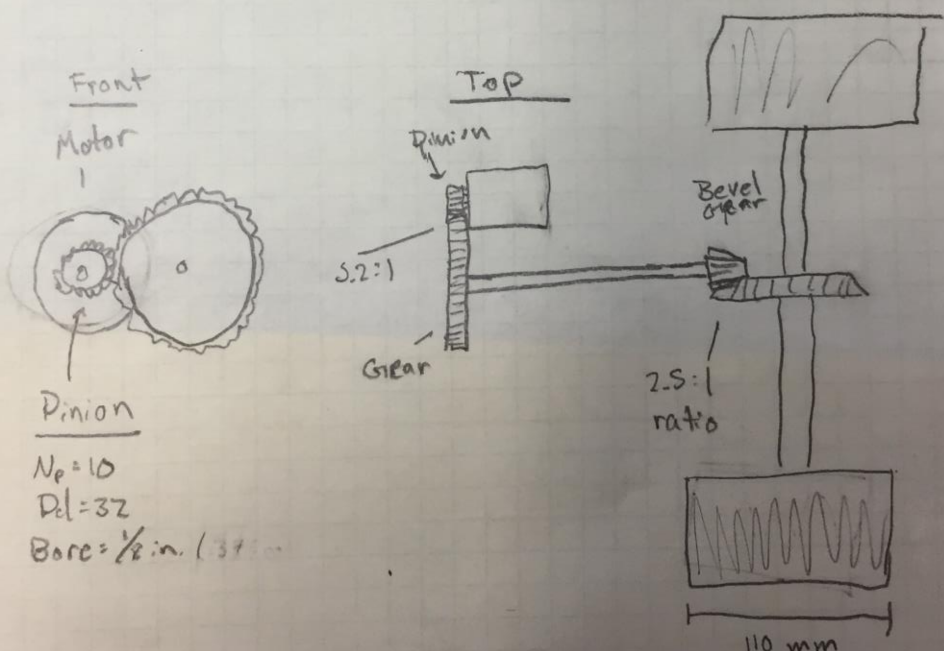
$$OD = \frac{N_P}{P_d} = \frac{10t}{32\ t/inch} = 0.3125\ in\ (7.94mm)$$

$$\text{Transmission Ratio} \times N_p = N_g$$

$$5.2 \times 10 = 52$$

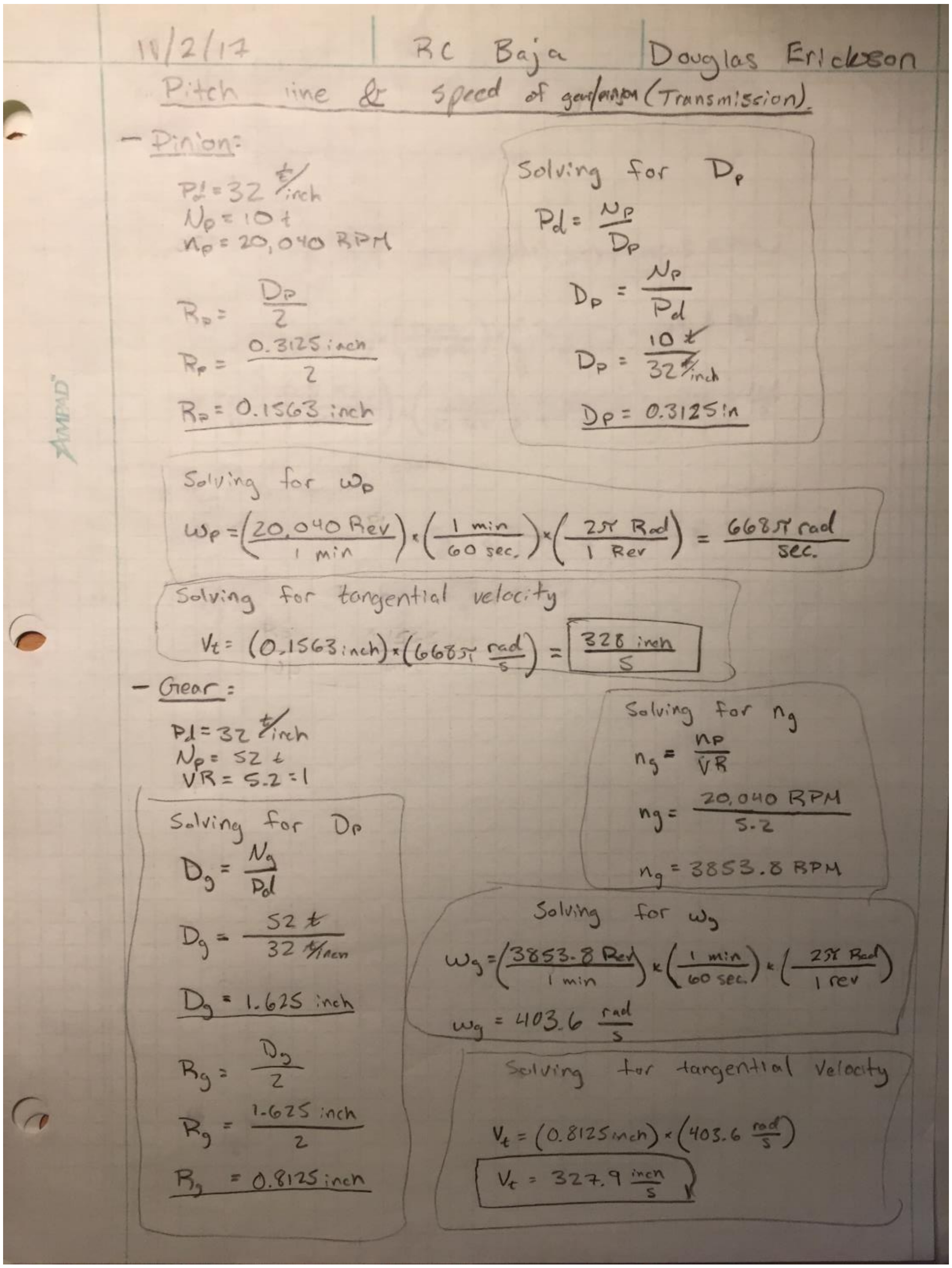
Gear Specs Traxxas Spur Gear, 52 tooth, 32 pitch

$P_d = 32$
$N_g = 52$
$OD = 43$ mm
$ID = 11$ mm



Appendix A.2

Subsequent to determining gear ratios is the design of the gears and their associated values. The outer diameter for the pinion is calculated using the pitch and number of teeth. The rotational speed of the pinion is used to calculated the angular velocity. The tangential velocity is then calculated by multiplying the angular velocity by the radius of the gear. These same calculations were performed identically for the gear.



11/2/17 | RC Baja | Douglas Erickson

Pitch line & speed of gear/pinion (Transmission).

– Pinion:

$P_d = 32$ t/inch

$N_p = 10$ t

$n_p = 20{,}040$ RPM

Solving for D_p

$$P_d = \frac{N_p}{D_p}$$

$$D_p = \frac{N_p}{P_d}$$

$$D_p = \frac{10\ t}{32\ t/inch}$$

$D_p = 0.3125$ in

$$R_p = \frac{D_p}{2}$$

$$R_p = \frac{0.3125\ inch}{2}$$

$R_p = 0.1563$ inch

Solving for ω_p

$$\omega_p = \left(\frac{20{,}040\ Rev}{1\ min}\right) \times \left(\frac{1\ min}{60\ sec.}\right) \times \left(\frac{2\pi\ Rad}{1\ Rev}\right) = \frac{668\pi\ rad}{sec.}$$

Solving for tangential velocity

$$V_t = (0.1563\ inch) \times \left(668\pi\ \frac{rad}{s}\right) = \boxed{328\ \frac{inch}{s}}$$

– Gear:

$P_d = 32$ t/inch

$N_p = 52$ t

$VR = 5.2 : 1$

Solving for n_g

$$n_g = \frac{n_p}{VR}$$

$$n_g = \frac{20{,}040\ RPM}{5.2}$$

$n_g = 3853.8$ RPM

Solving for D_g

$$D_g = \frac{N_g}{P_d}$$

$$D_g = \frac{52\ t}{32\ t/inch}$$

$D_g = 1.625$ inch

$$R_g = \frac{D_g}{2}$$

$$R_g = \frac{1.625\ inch}{2}$$

$R_g = 0.8125$ inch

Solving for ω_g

$$\omega_g = \left(\frac{3853.8\ Rev}{1\ min}\right) \times \left(\frac{1\ min}{60\ sec.}\right) \times \left(\frac{2\pi\ Rad}{1\ rev}\right)$$

$\omega_g = 403.6\ \frac{rad}{s}$

Solving for tangential Velocity

$$V_t = (0.8125\ inch) \times \left(403.6\ \frac{rad}{s}\right)$$

$$\boxed{V_t = 327.9\ \frac{inch}{s}}$$

Appendix A.3

11/2/17 | RC Baja | Doug Erickson

Pitch Line & Speed of gear/pinion (Differential)

- Gear: $N_g = 36$, $n_g = 1552.2$ RPM, $P_d = 32\ T/\text{inch}$, $\omega_g = 162.5\ \frac{\text{rad}}{s}$

Solving for D_g

$$P_d = \frac{N_g}{D_p}$$

$$D_g = \frac{36\,t}{32\ t/\text{inch}}$$

$$D_g = 1.125\ \text{inch}$$

$$R_g = \frac{D_g}{2}$$

$$R_g = \frac{1.125\ \text{inch}}{2}$$

$$R_g = 0.563\ \text{inch}$$

Solving for V_{tg}

$$V_{tg} = (R_g)(\omega_g) = (0.563\ \text{inch})\left(162.5\ \frac{\text{rad}}{s}\right) = \boxed{91.4\ \frac{\text{inch}}{s}}$$

- Pinion: $N_p = 14\ t$, $P_d = 32\ t/\text{inch}$, $\omega_p = 406.1\ \frac{\text{rad}}{s}$

Solving for D_p

$$D_p = \frac{N_p}{P_d}$$

$$D_p = \frac{14\ t}{32\ t/\text{inch}}$$

$$D_p = 0.438\ \text{inch}$$

$$R_p = \frac{D_p}{2}$$

$$R_p = \frac{0.438\ \text{inch}}{2}$$

$$R_p = 0.219\ \text{inch}$$

Solving for V_{tp}

$$V_{tp} = (R_p)(\omega_p) = (0.219\ \text{inch})\left(406.1\ \frac{\text{rad}}{s}\right) = \boxed{88.8\ \frac{\text{inch}}{s}}$$

Appendix A.4

10/15/17 | RC Baja | Douglas Erickson

Gear and Pinion Design (Differential)

Given: $VR = 2.5:1$
Axle RPM = 1552.2 RPM

Axle RPM = n_g

$$n_p = n_g (VR) = (1552.2\,\text{RPM})(2.5) = \boxed{3880.5\ \text{RPM}}$$

$$\omega_g = \left(\frac{1552.2\ \text{rev}}{1\ \text{min}}\right) \times \left(\frac{1\ \text{min}}{60\ \text{sec}}\right) \times \left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right) = 162.5\ \frac{\text{rad}}{\text{s}}$$

$$\omega_p = \left(\frac{3880.5\ \text{Rev}}{1\ \text{min}}\right) \times \left(\frac{1\ \text{min}}{60\ \text{sec}}\right) \times \left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right) = 406.4\ \frac{\text{rad}}{\text{s}}$$

— Using VR to find gears
* Axial AXI30401

Does AXI30401 satisfy a VR of 2.5:1?

$N_p = 36$
$N_g = 14$

$$\frac{N_p}{N_g} = \frac{36}{14} = 2.57 \checkmark$$

Appendix A.5

11/18/17 | RC Baja | Douglas Erickson

Differential: Solving for Mounting distance (M_{dG})

$OD_p = 14\,mm$ Gear depth = 2mm

thickness = 3mm

$OD_g = 12\,mm$

$$M_{dG} \approx \left(\frac{OD_p}{2}\right) + \left(\frac{OD_g}{2}\right) + \left(\frac{GD}{2}\right)$$

$$\approx \left(\frac{14mm}{2}\right) + \left(\frac{12mm}{2}\right) + \left(\frac{2mm}{2}\right)$$

$$\approx \boxed{14mm}$$

Differential: Case Length

$$\text{Case Length (Internal)} = (M_{dG}) \cdot 2$$

$$= (14mm) \cdot 2$$

$$= \boxed{28mm}$$

$$\text{Case Length (External)} = CL_i + (2)(\text{thickness})$$

$$= 28mm + (2)(3mm)$$

$$= \boxed{34mm}$$

Appendix A.6

10/29/17 | RC Baja | Douglas Erickson

R.A.Q.D.

Requirement: Axles must withstand full force of motor

Motor PWR = 90W

Analysis:

- Assuming no power loss through drive train; gear loss = 0

$$P_{in} = P_{out} + \text{gear loss}$$

$$\frac{P_{out}}{\omega} = \frac{T\omega}{\omega} \qquad T = \frac{P_{out}}{\omega}$$

From page 2: $\omega = 162.5 \frac{rad}{s}$

Standard Steel
$E = 201 GPa$
$\nu = 0.29$
$G = 80.0 GPa$

$$T = \frac{P_{out}}{\omega} = \frac{90W}{162.5 \frac{rad}{s}} = 0.55 N\text{-}m$$

$$\tau = \frac{Tr}{J} \qquad J = \frac{\pi}{32}(D^4) \qquad J = \frac{\pi}{32}(r^4)$$

$$\tau = \frac{T\cancel{r}}{\frac{\pi}{32} r^4}$$

$$E = \frac{\tau}{\gamma}$$

$$r = \frac{T(32)}{\pi(\tau)}$$

$$\gamma = \frac{r\theta}{L}$$

$$E = \frac{\left(\frac{Tr}{J}\right)}{\left(\frac{rT}{JG}\right)}$$

$$G =$$

$$\theta = \frac{TL}{JG}$$

$$E = \frac{\cancel{Tr} JG}{Tr J}$$

$$\gamma = \frac{r\left(\frac{TL}{JG}\right)}{\cancel{L}}$$

$$\gamma = \frac{rT}{JG}$$

$$D = \frac{(64)(0.55 N\text{-}m)}{\pi (394720{,}000 Pa)}$$

$$D =$$

$\tau = E(\gamma)$ $\theta = \frac{TL}{JG}$

$\tau = E($ $= \_\_\_$

Rule will not deflect

$$\left(\frac{G}{\tau}\right) E = \tau$$

$$G\left(\frac{J}{Tr}\right) E = \frac{Tr}{J}$$

$$\sqrt{(G)(E)} = \sqrt{\frac{T^2 r^2}{J^2}}$$

$$\sqrt{(G)(E)} = \frac{Tr}{J}$$

$$\sqrt{(G)(E)} = \frac{T\cancel{r}}{\frac{\pi}{2}(r^{\cancel{4}})}$$

$$\sqrt{(G)(E)} = \frac{T}{\frac{\pi}{2}(r^3)}$$

$$r^3 = \frac{T}{\left(\frac{\pi}{2}\right)\left((G)(E)\right)^{\frac{1}{2}}}$$

$$r = \sqrt[3]{\frac{T}{\left(\frac{\pi}{2}\right)(GE)^{\frac{1}{2}}}}$$

$$r = \sqrt{\frac{(0.55\ N \cdot m)}{\left(\frac{\pi}{2}\right)\left((200 \times 10^9\ Pa)(90 \times 10^9\ Pa)\right)^{\frac{1}{2}}}}$$

$$\boxed{r = 1.1\ mm}$$

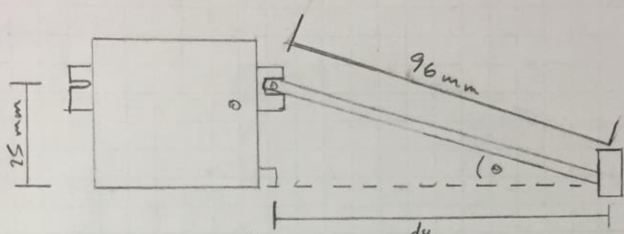
Appendix A.7

11/29/17 | RC Baja | Douglas Frickson

Given: CVD joint Length, Differential Height

Find: Angle of drive shaft (θ) [Must be less than 30°]

Soln:



Solving for dx

$$dx = \sqrt{(CVD_L)^2 - (h)^2}$$

$$dx = \sqrt{(96mm)^2 - (25mm)^2}$$

$$\boxed{dx = 92.7\ mm}$$

Solving For θ

$$\theta = \tan^{-1}\left(\frac{dy}{dx}\right)$$

$$\theta = \tan^{-1}\left(\frac{25mm}{92.7mm}\right)$$

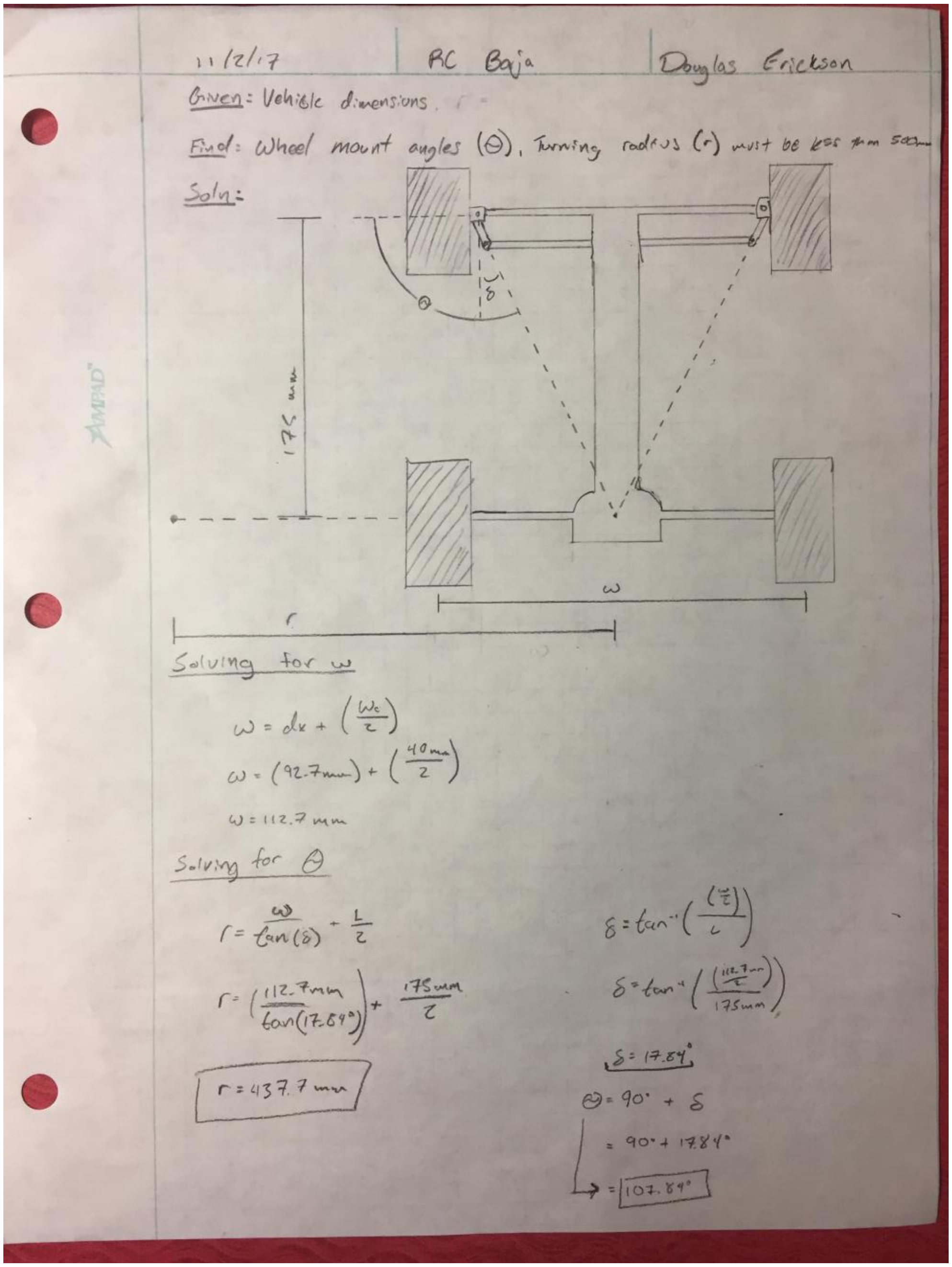
$$\boxed{\theta = 15.09°}$$

Actual vs. Requirement

15.09° < 30° ✓

Appendix A.8

The major requirement placed on the steering assembly is to allow the vehicle a turning radius of less than 500mm (1.6ft). The overall length of the vehicle is determined initially by the space required from the components on the vehicle. Using the Ackermann steering geometry, the length and width are used to calculated the angle of the steering arm. This steering principle provides non-slip steering which in turn reduces wear on tires. The resulting angle is used in the Ackerman radius equation to calculate the current radius. While the current length of the vehicle allows for a turning radius of under 500mm, failure to do so would result in redesign of the overall chassis length and width.



Appendix A.9

11/27/17 RC Baja Douglas Erickson

Given: W, u, B, E

Find: Torque required for steering, must be less than (4.1 kg/cm)

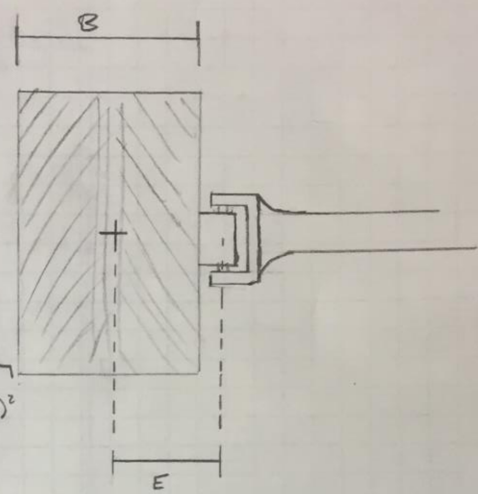
Soln:

$B = 43\,mm$

$E = 28.5\,mm$

Assume $u = 0.7$

$W = 1.94\,kg$



$$T = Wu\sqrt{\frac{B^2}{8} + E^2}$$

$$T = (1.94\,kg)(.7)\sqrt{\frac{(4.3\,cm)^2}{8} + (2.85\,cm)^2}$$

$\boxed{T = 4.39\ kg\text{-}cm}$ ← @ kingpin

Appendix A.10

11/27/17 BC Baja Douglas Erickson

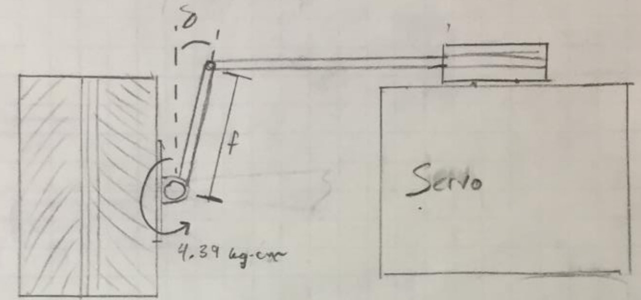
Given: $T_{@kingpin}$, T_{servo}

Find: Steering Arm length (f) so that $T_{servo} = (0.4) T_{@kingpin}$

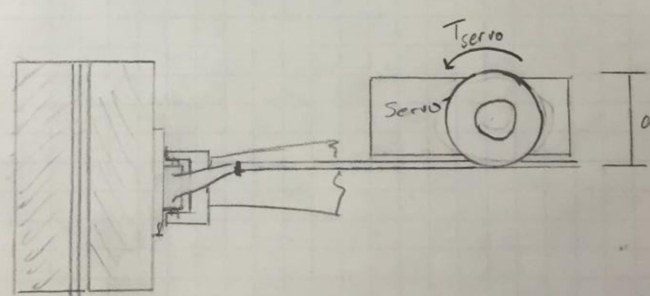
Soln:

$\delta = 17.84°$
$d = 23$ mm (2.3cm)

Top



Front



$$\left(\frac{T_{kn}}{f}\right) = \left(\frac{T_{servo}}{\left(\frac{d}{2}\right)}\right)$$

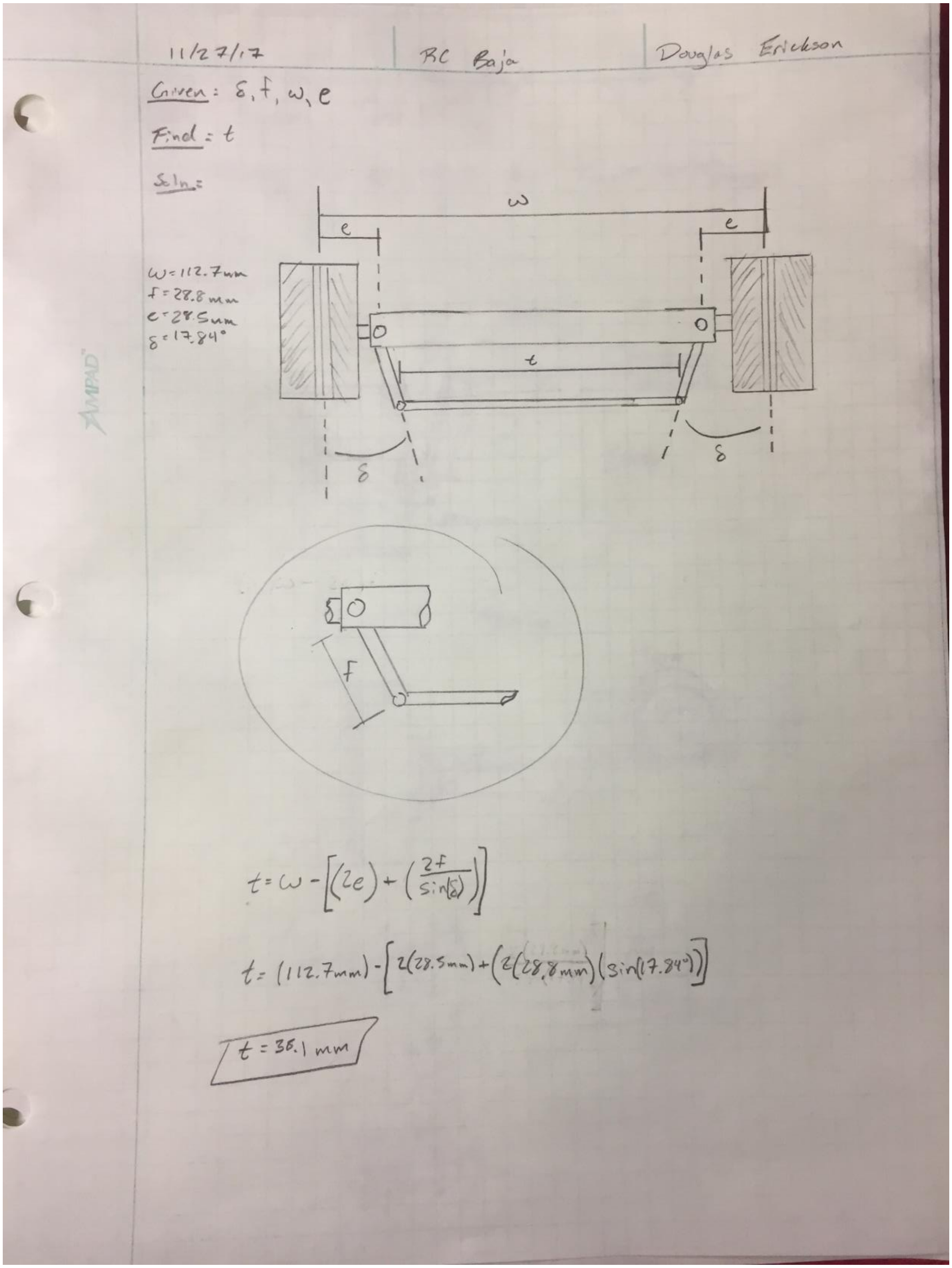
$$\left(\frac{T_{kn}}{f}\right) = \left(\frac{T_{kn}(0.4)}{\left(\frac{d}{2}\right)}\right)$$

$$f = \left(\frac{\left(\frac{d}{2}\right)(T_{kn})}{(T_{kn})(0.4)}\right)$$

$$f = \frac{\left(\frac{d}{2}\right)}{0.4}$$

$$\boxed{f = 2.875 \text{ cm}}$$

Appendix A.11



Given: δ, f, ω, e

Find: t

Soln.:

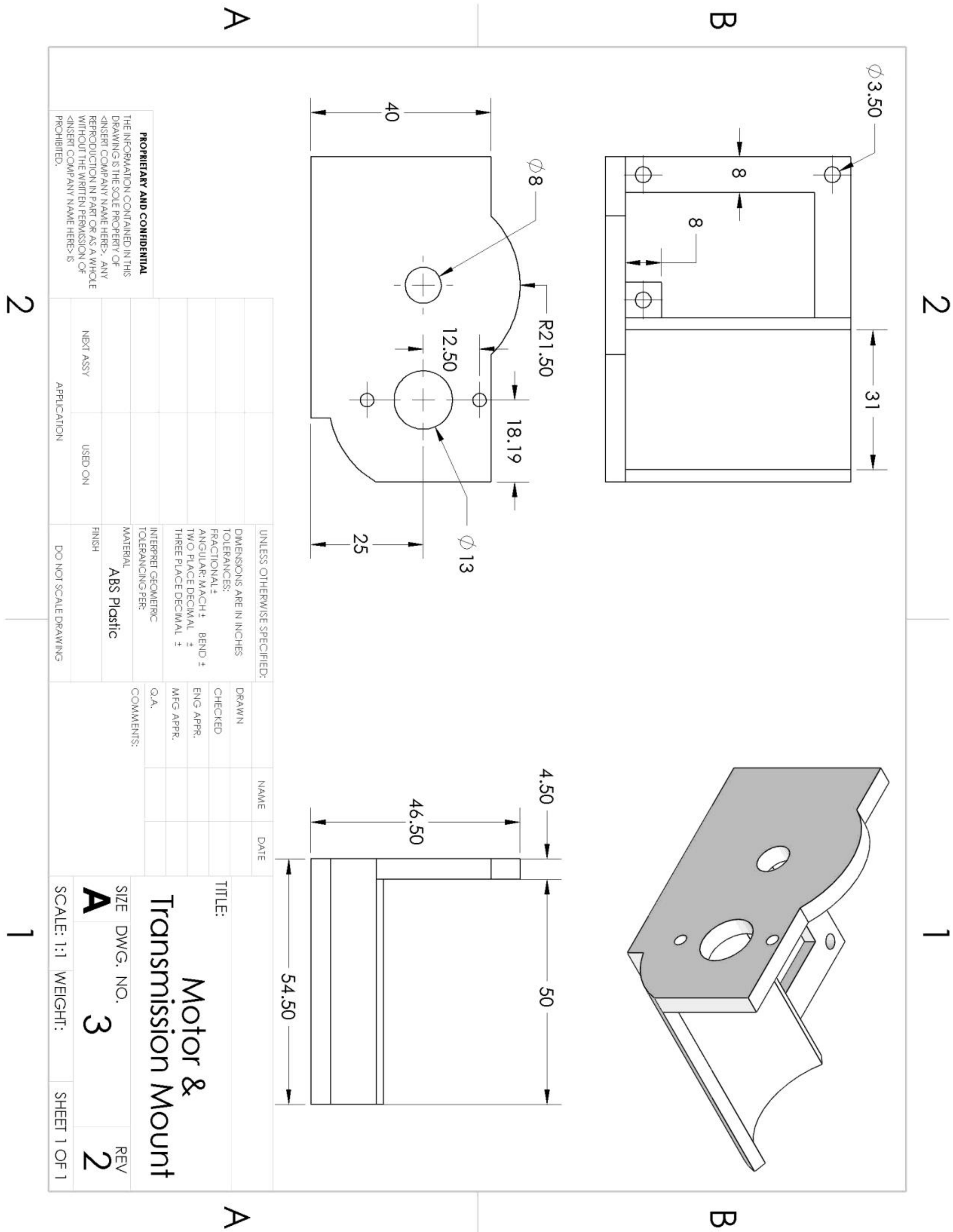
$\omega = 112.7\,mm$
$f = 28.8\,mm$
$e = 28.5\,mm$
$\delta = 17.84°$

$$t = \omega - \left[(2e) + \left(\frac{2f}{\sin(\delta)}\right)\right]$$

$$t = (112.7\,mm) - \left[2(28.5\,mm) + \left(2(28.8\,mm)(\sin(17.84°))\right)\right]$$

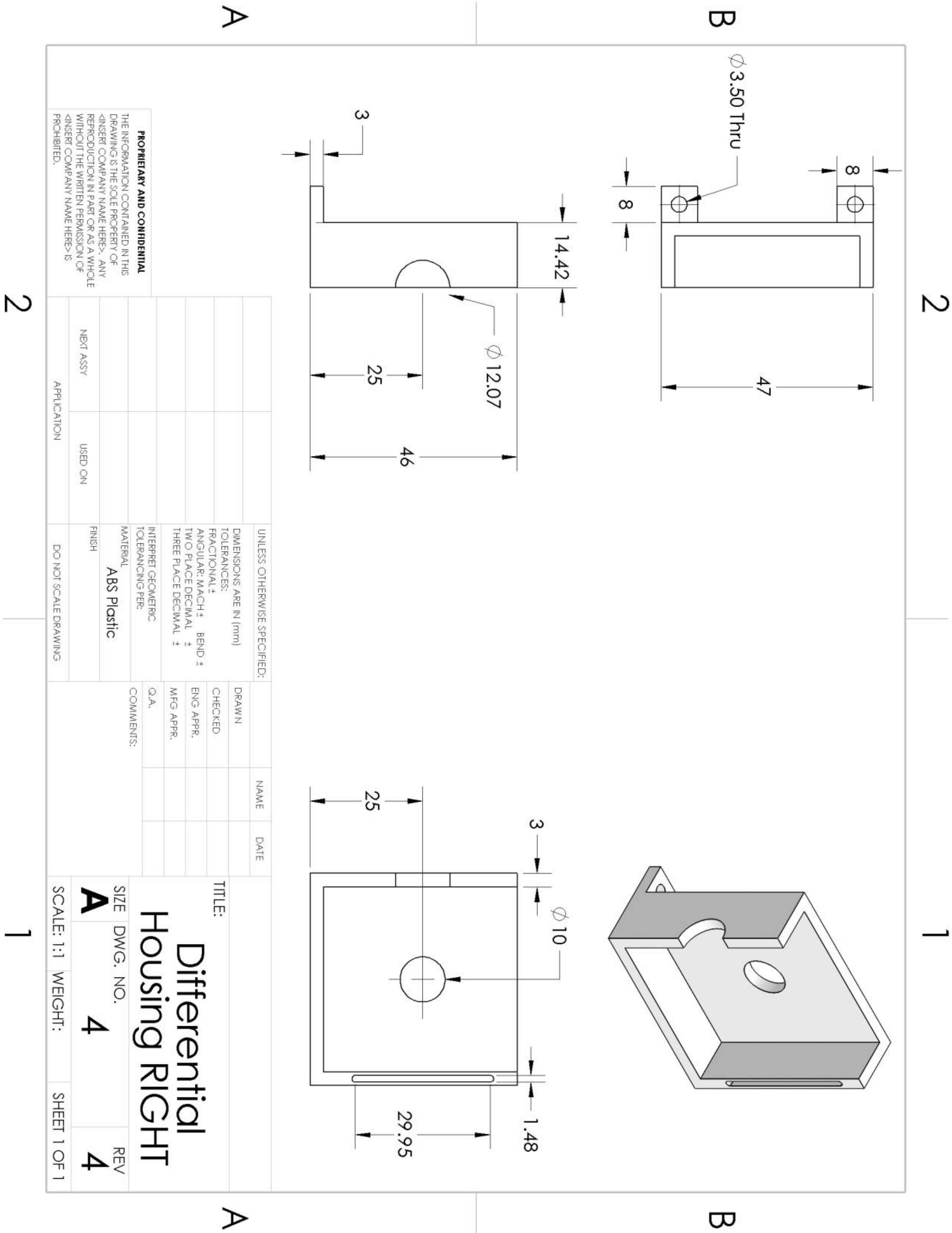
$$\boxed{t = 36.1\,mm}$$

Appendix B.1



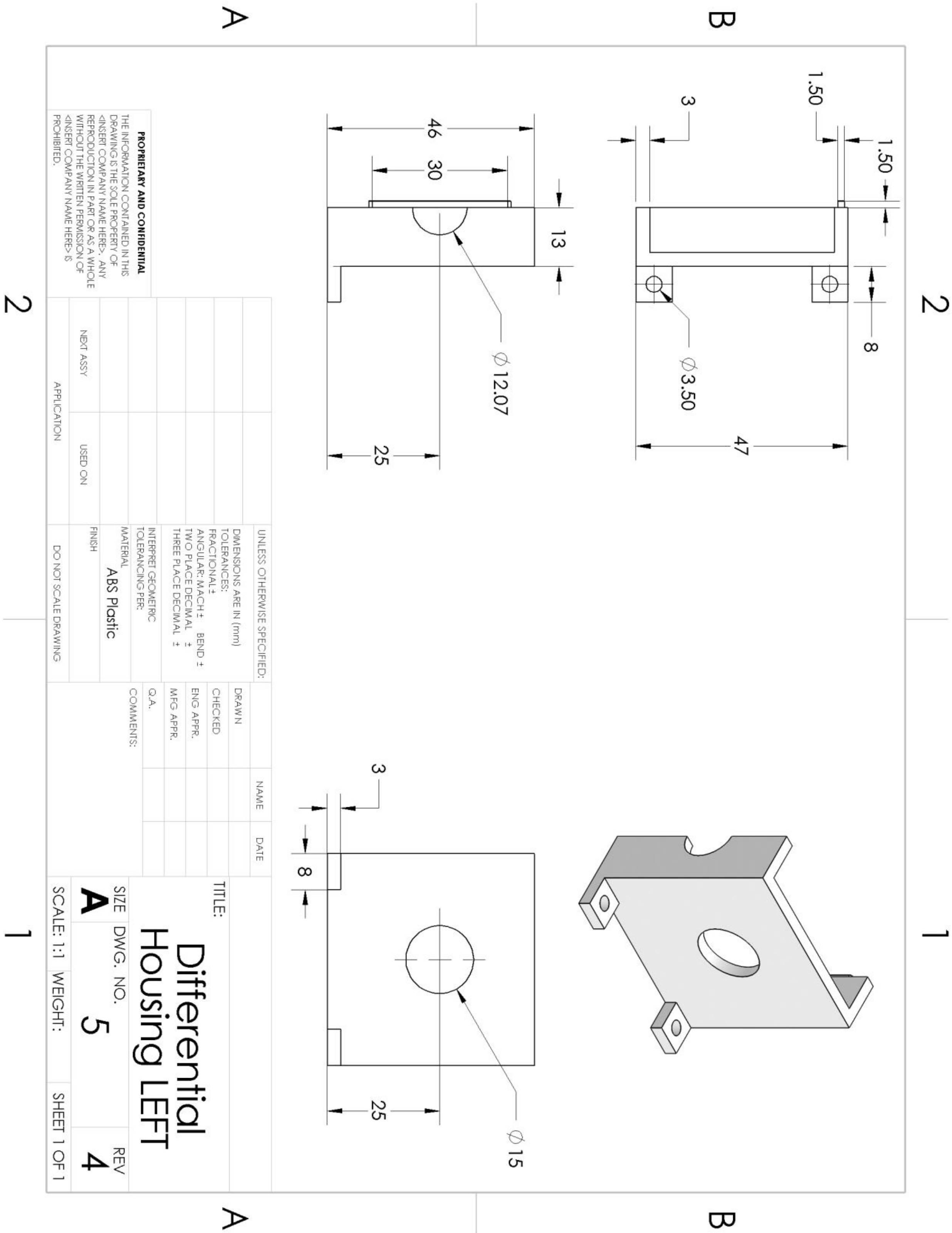
Motor & Transmission Mount
ABS Plastic
SIZE A
DWG. NO. 3
REV 2
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
TITLE:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
Ø3.50
8
8
31
40
Ø8
R21.50
12.50
18.19
25
Ø13
4.50
46.50
50
54.50

Appendix B.2



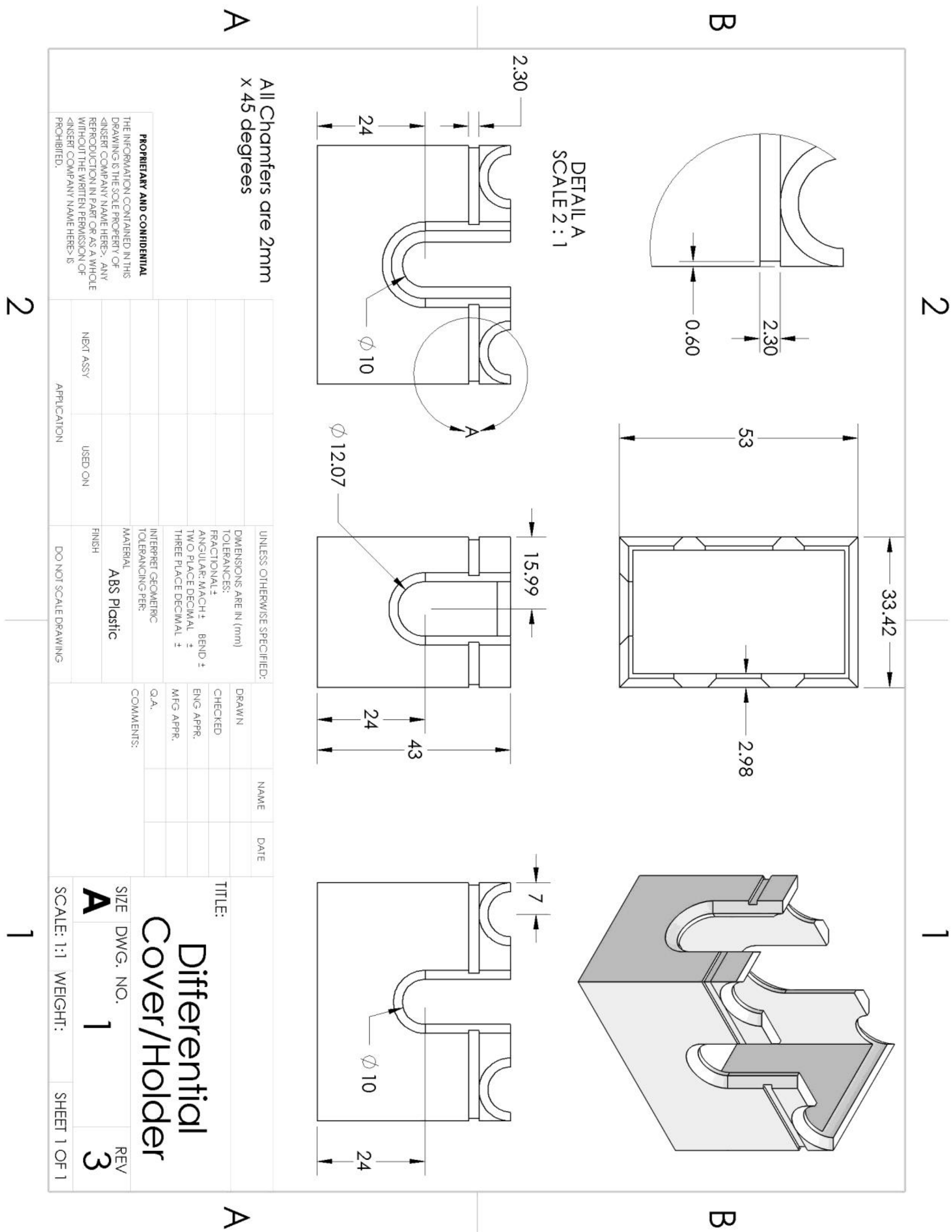
Differential Housing RIGHT
ABS Plastic
Ø3.50 Thru
Ø12.07
Ø10
14.42
47
46
25
29.95
1.48
8
3
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN (mm)
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
SIZE
A
DWG. NO.
4
REV
4
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1

Appendix B.3



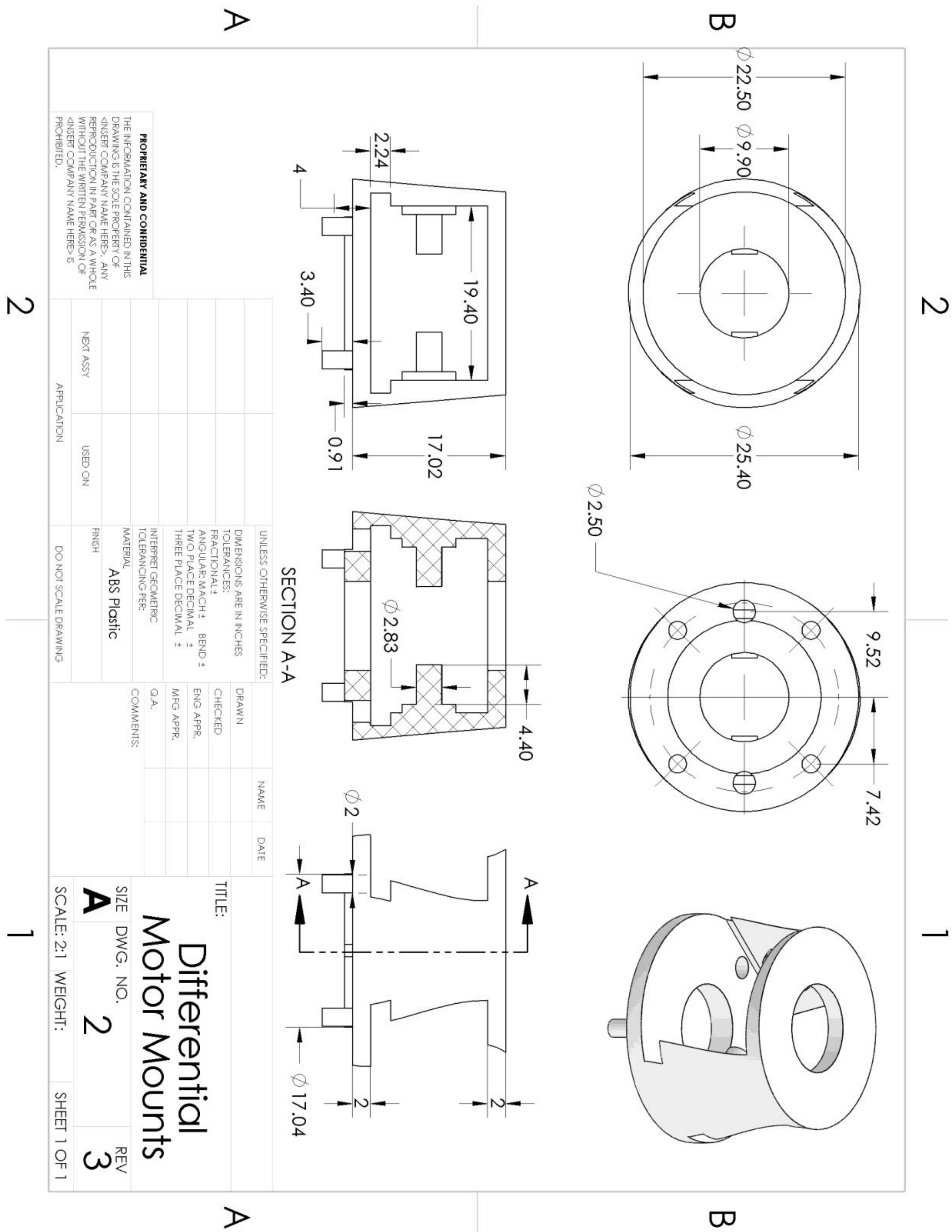
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN (mm)
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS Plastic
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Differential Housing LEFT
SIZE
A
DWG. NO.
5
REV
4
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
A
B
2
1
46
30
13
25
Ø12.07
3
1.50
1.50
8
47
Ø3.50
Ø15

Appendix B.4

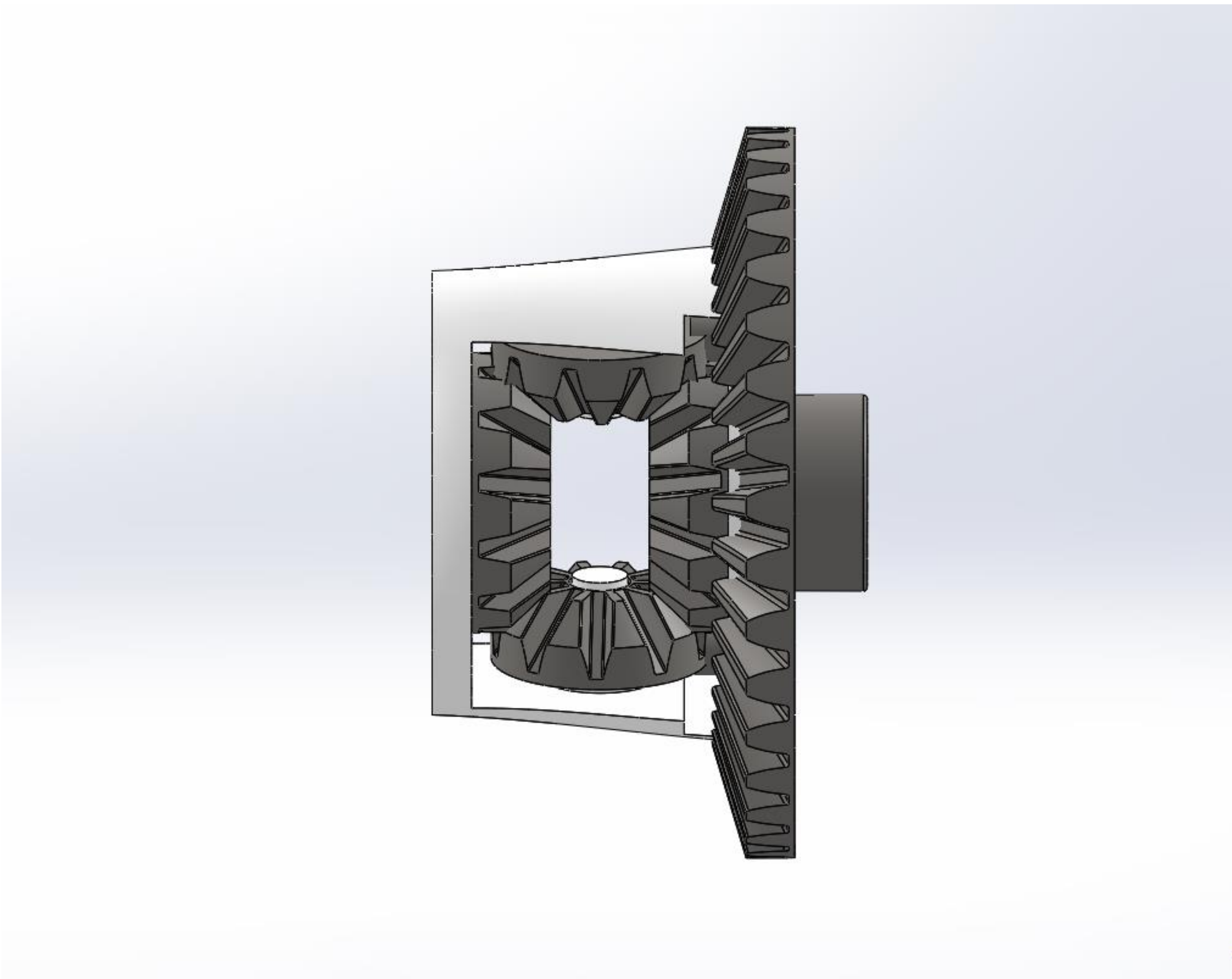


DETAIL A
SCALE 2 : 1
All Chamfers are 2mm
x 45 degrees
2.30
24
0.60
2.30
53
33.42
2.98
15.99
∅ 10
∅ 12.07
A
24
43
7
∅ 10
24
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN (mm)
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS Plastic
FINISH
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
Differential Cover/Holder
SIZE
A
DWG. NO.
1
REV
3
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
A
B
1
2

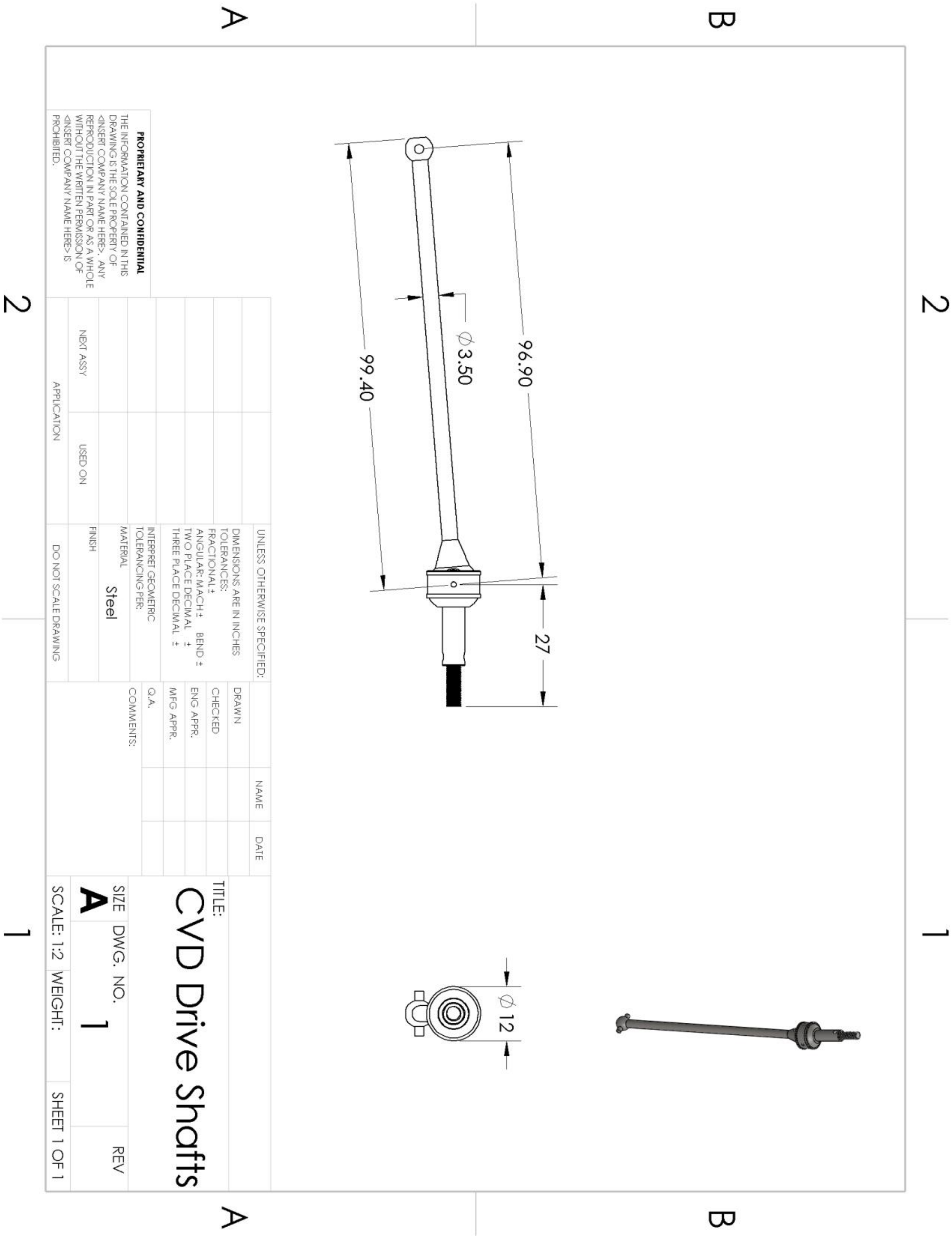
Appendix B.5


SECTION A-A
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
MATERIAL
ABS Plastic
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
Differential Motor Mounts
SIZE
A
DWG. NO.
2
REV
3
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1

Appendix B.6

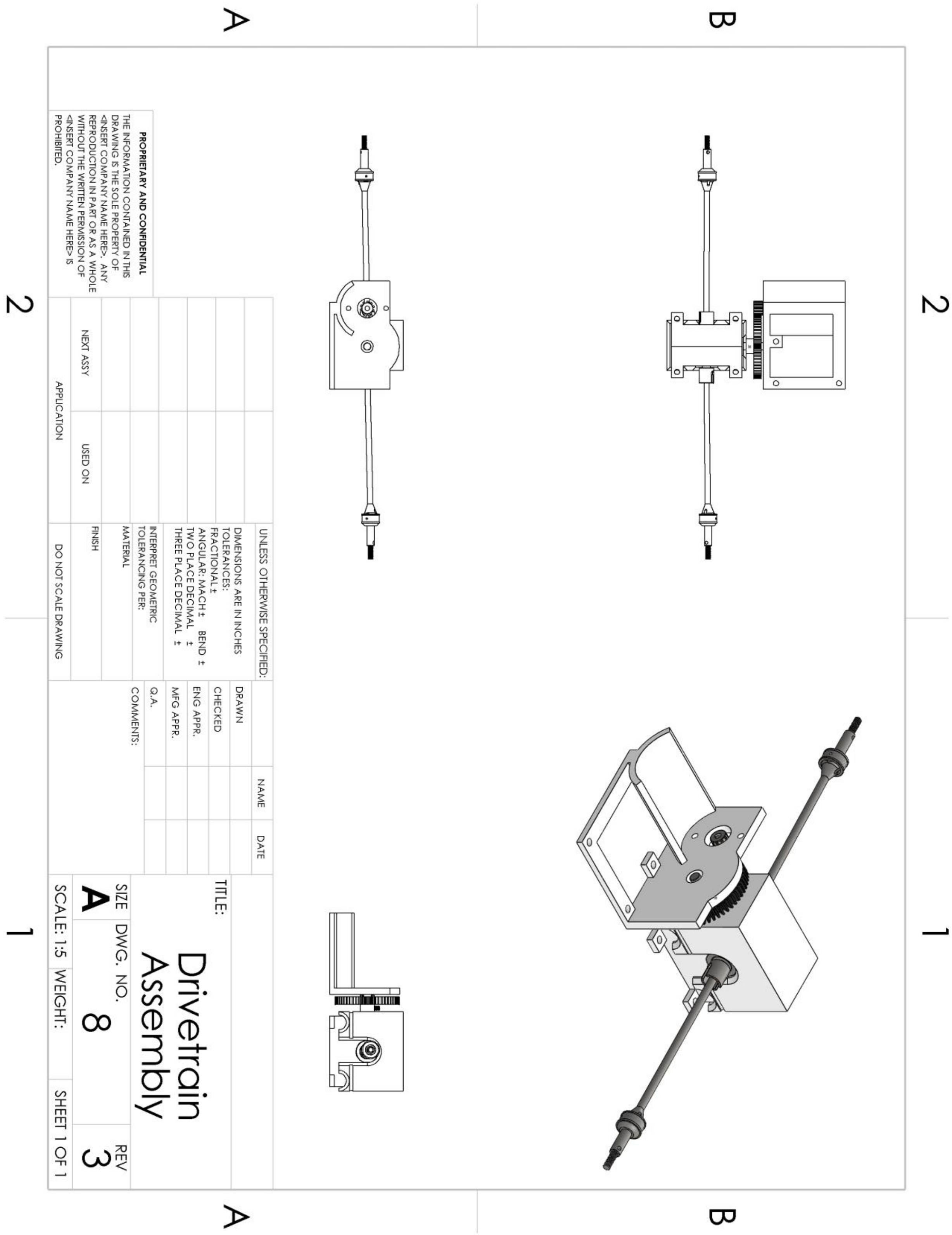


Appendix B.7

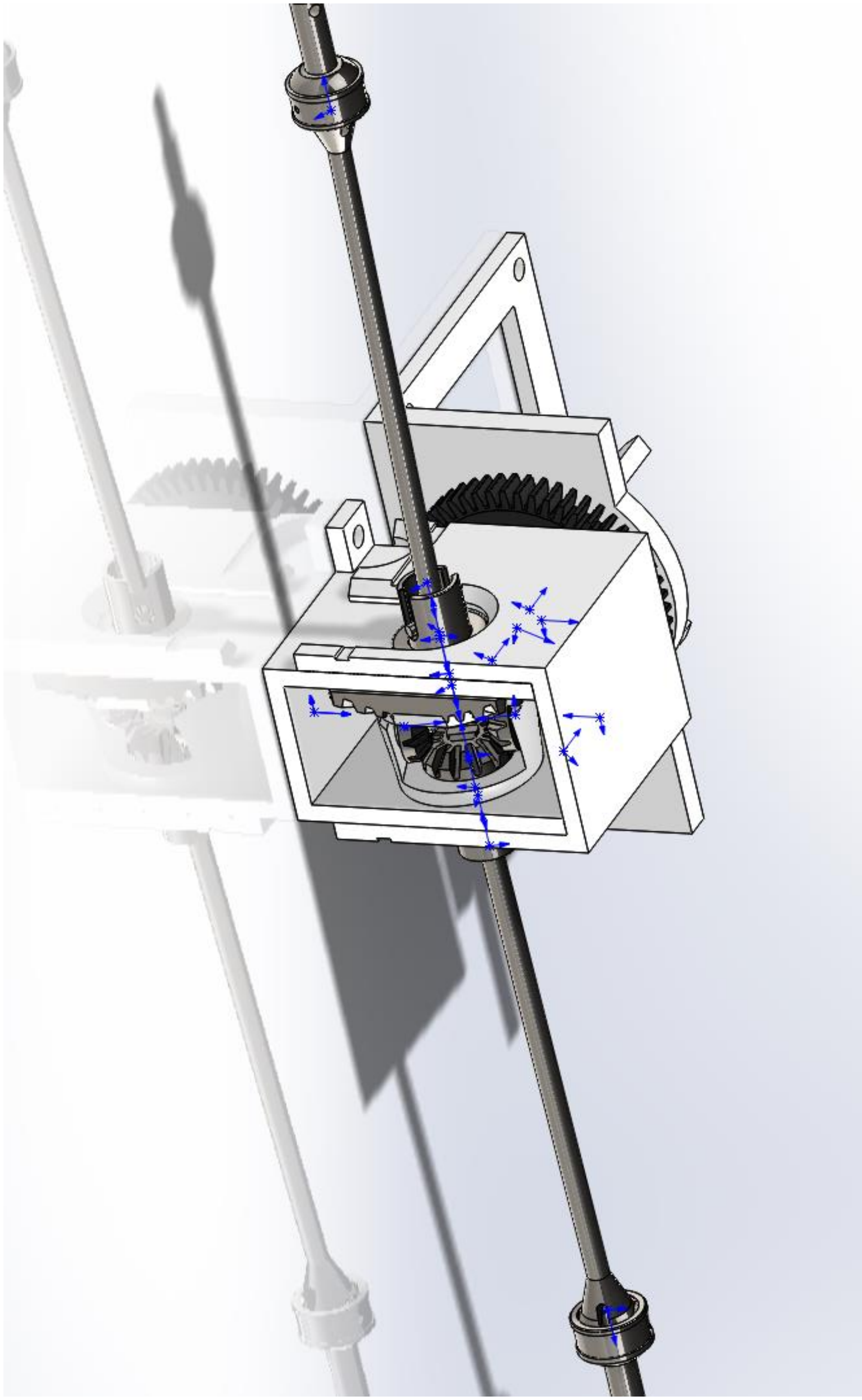


99.40
96.90
Ø3.50
27
Ø12
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
CVD Drive Shafts
SIZE
A
DWG. NO.
1
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

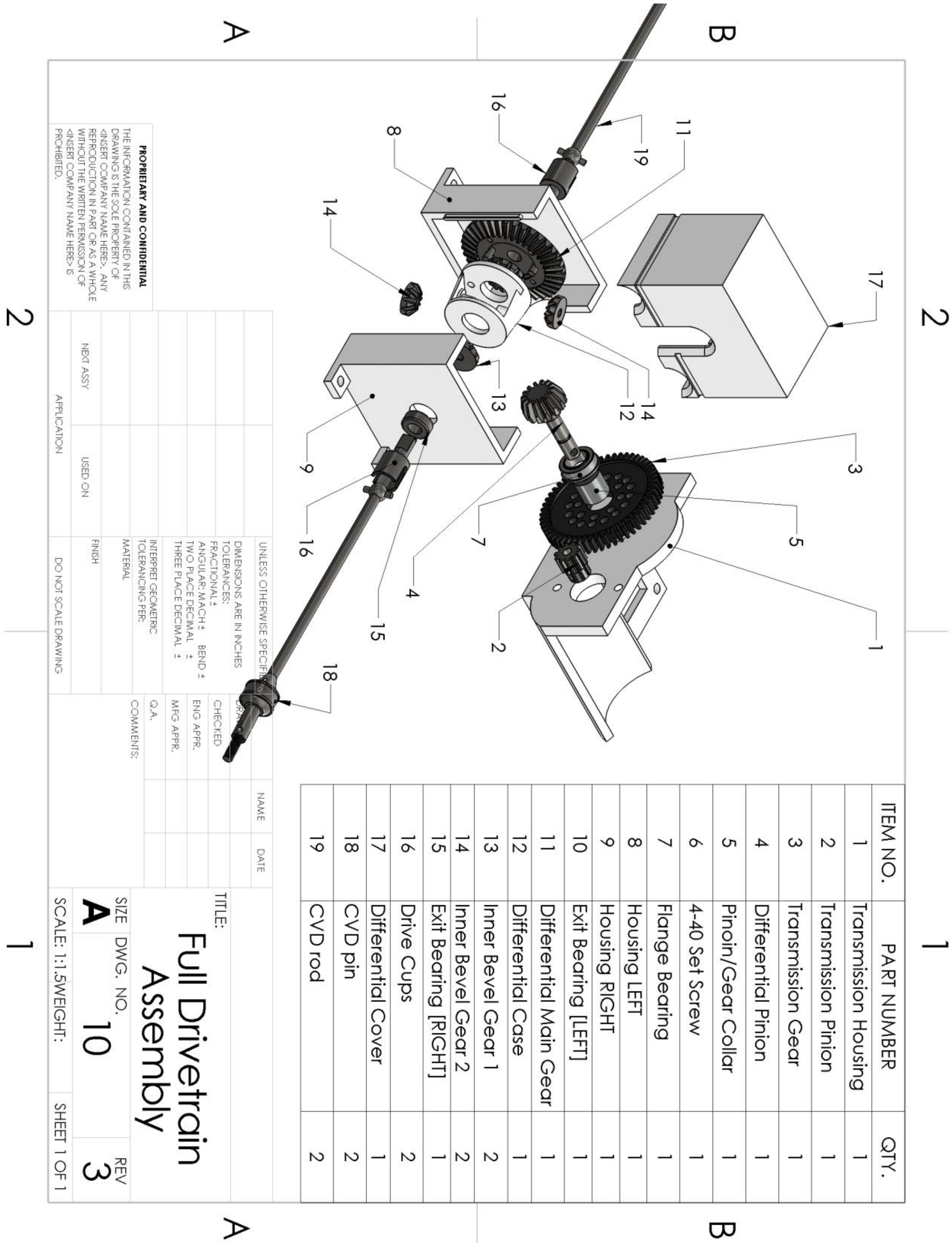
Appendix B.8


PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Drivetrain Assembly
SIZE
A
DWG. NO.
8
REV
3
SCALE: 1:5
WEIGHT:
SHEET 1 OF 1
A
B
1
2

Appendix B.9

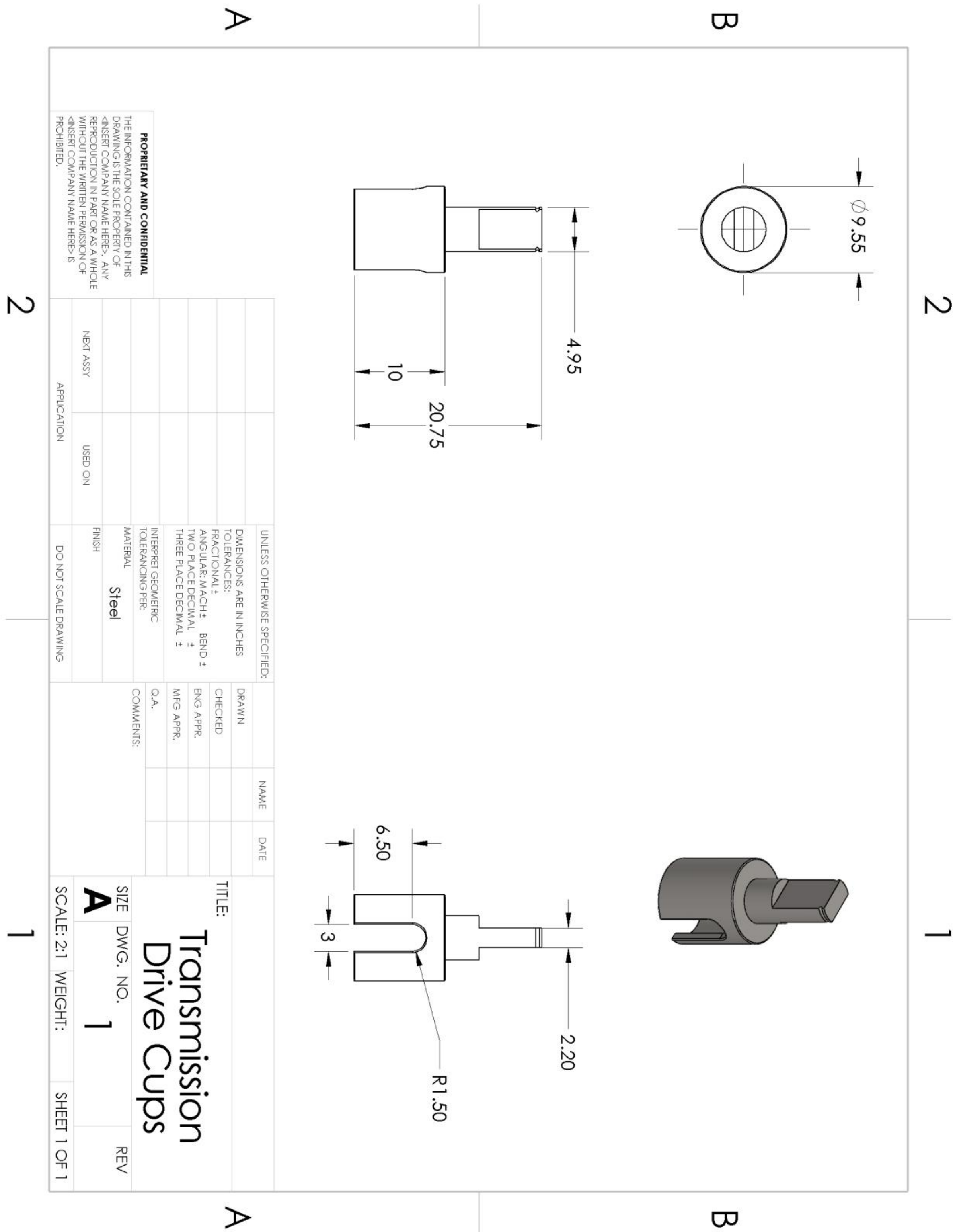


Appendix B.10

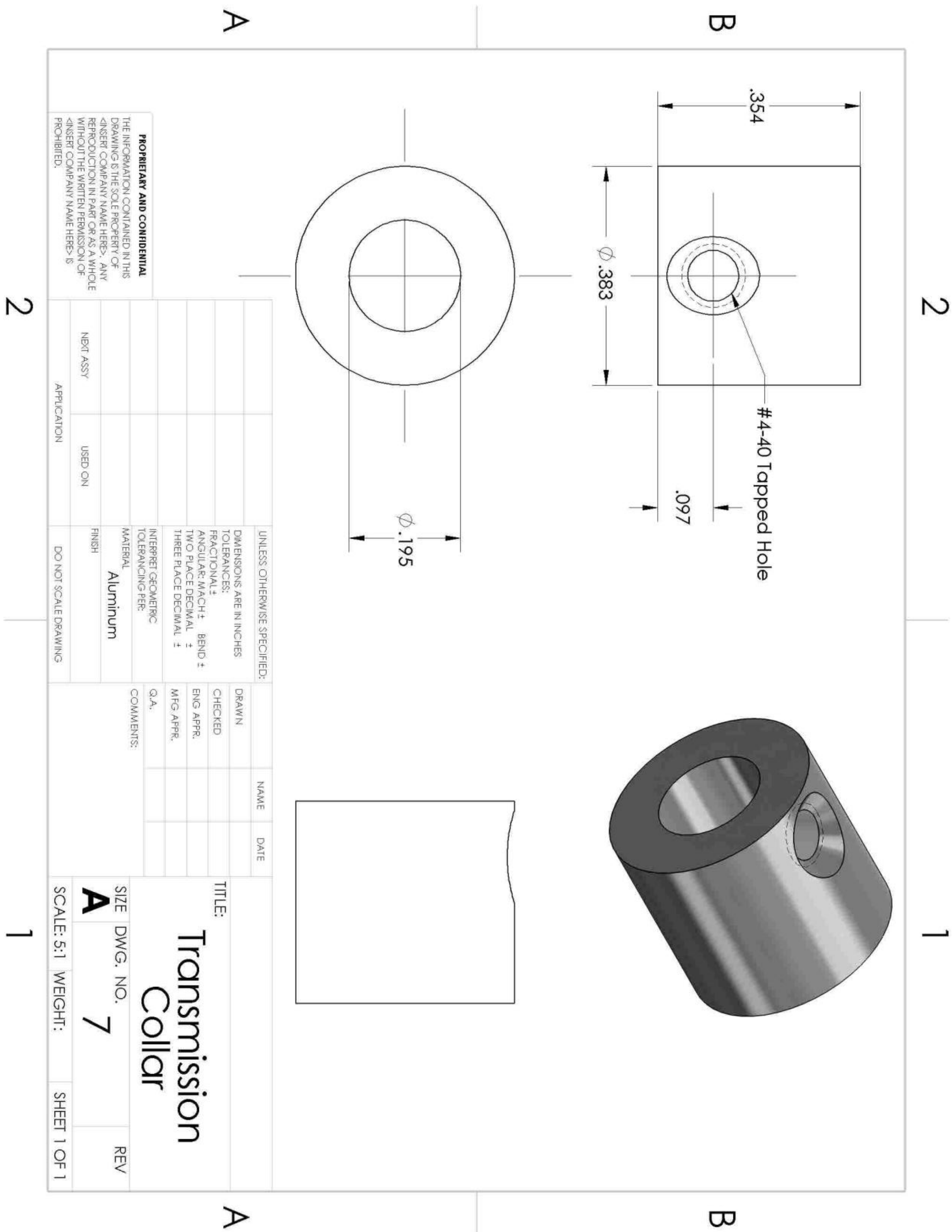


ITEM NO.	PART NUMBER	QTY.
1	Transmission Housing	1
2	Transmission Pinion	1
3	Transmission Gear	1
4	Differential Pinion	1
5	Pinoin/Gear Collar	1
6	4-40 Set Screw	1
7	Flange Bearing	1
8	Housing LEFT	1
9	Housing RIGHT	1
10	Exit Bearing [LEFT]	1
11	Differential Main Gear	1
12	Differential Case	1
13	Inner Bevel Gear 1	2
14	Inner Bevel Gear 2	2
15	Exit Bearing [RIGHT]	1
16	Drive Cups	2
17	Differential Cover	1
18	CVD pin	2
19	CVD rod	2

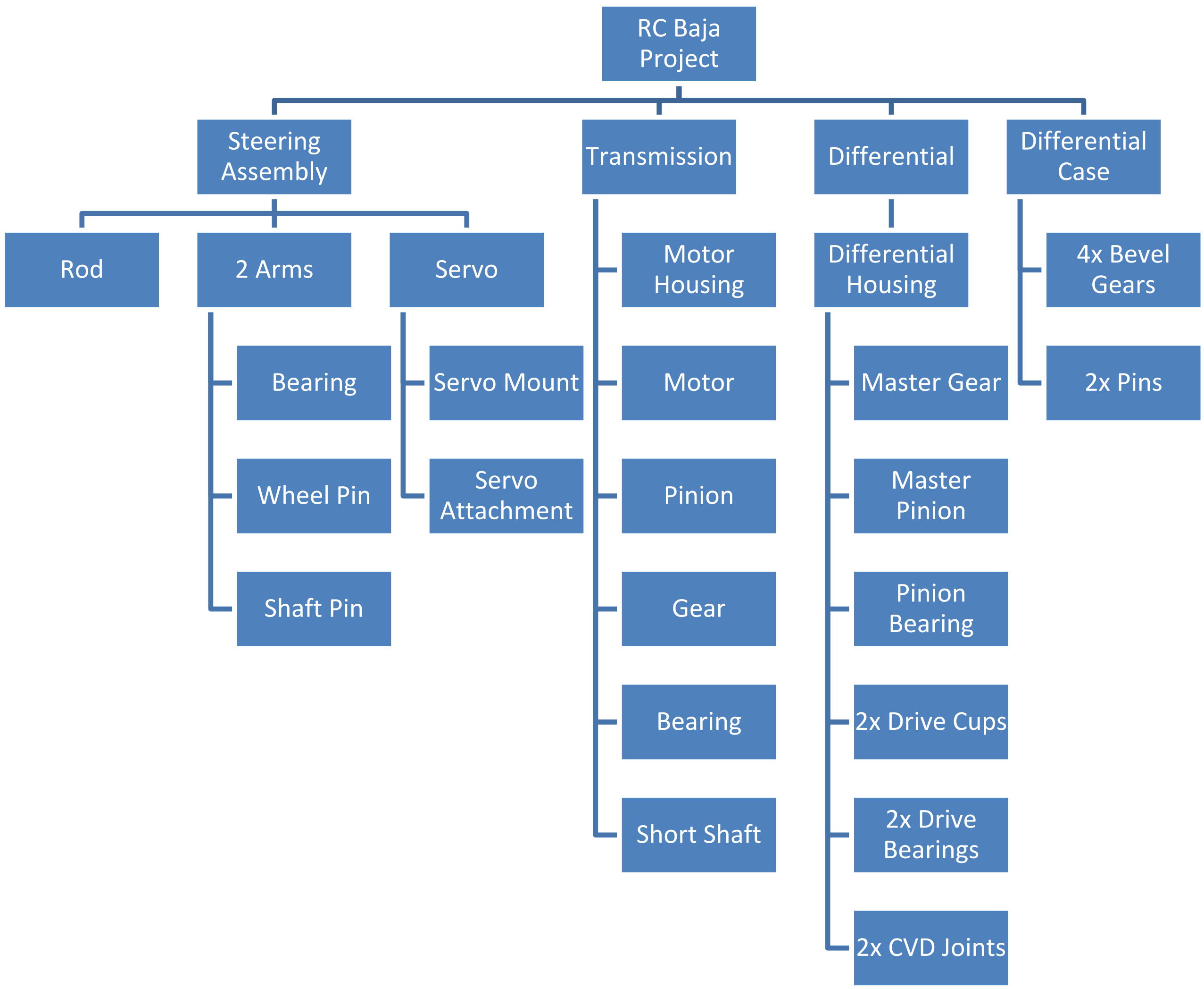
Appendix B.11

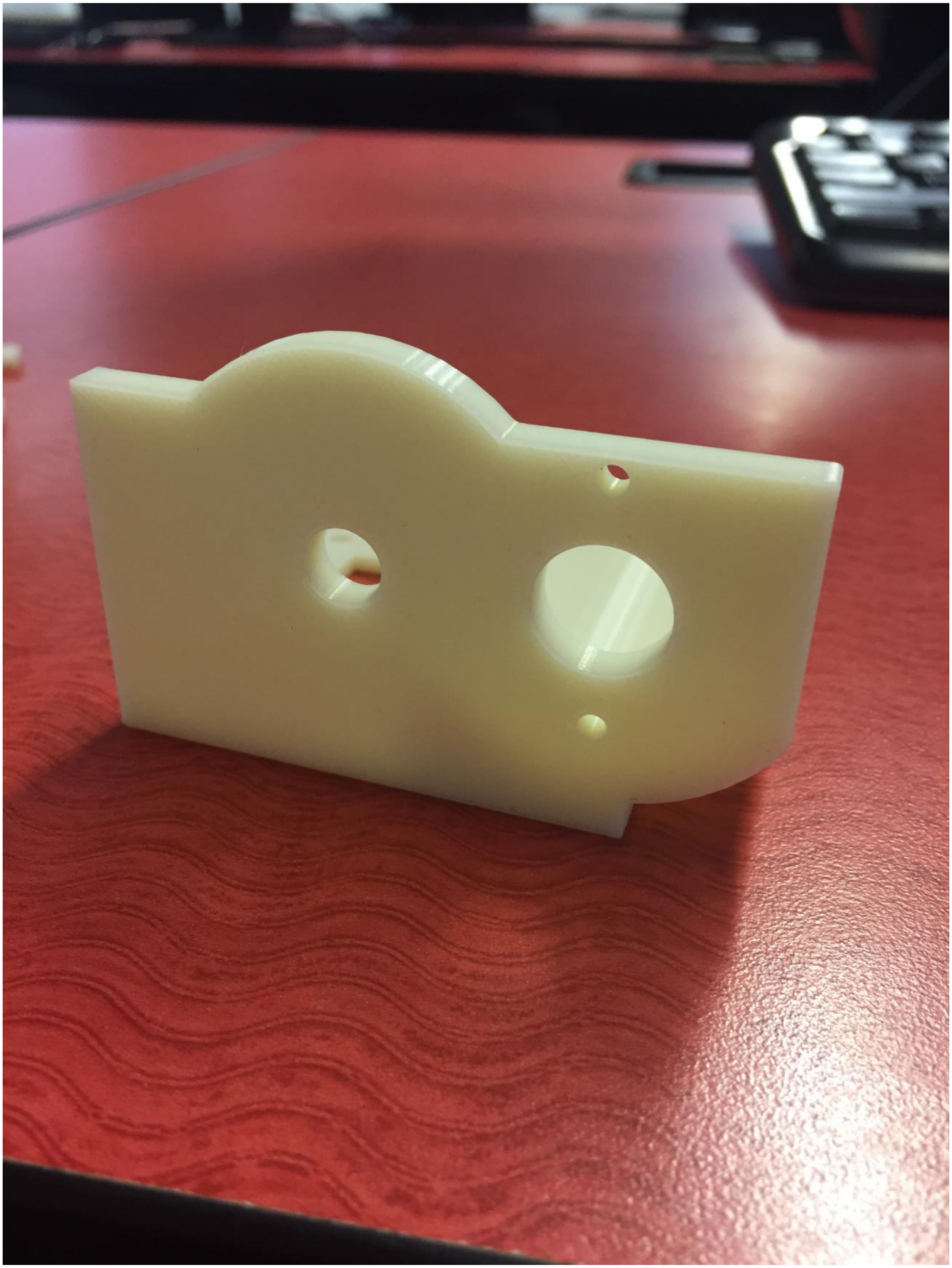


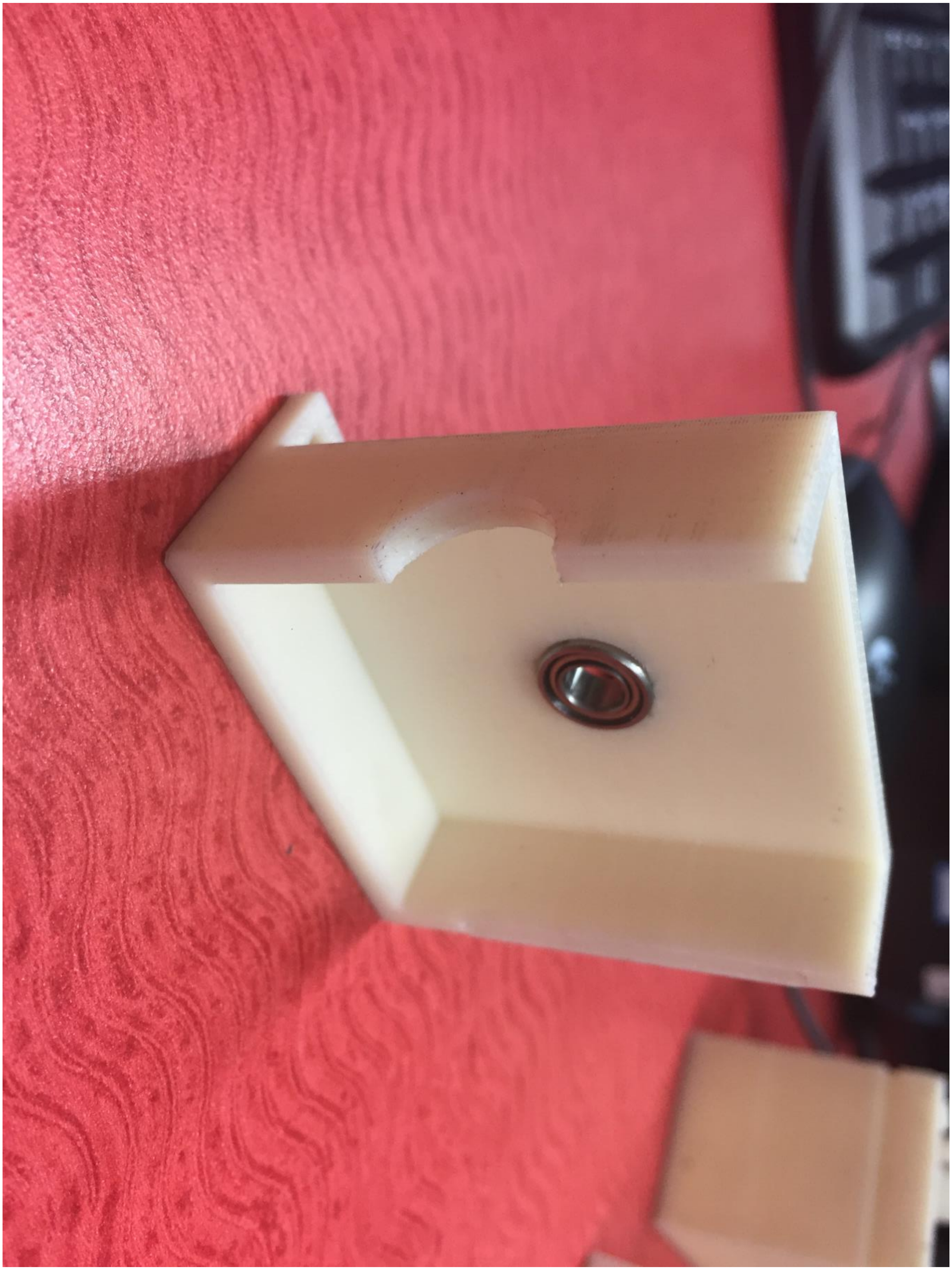
Appendix B.12

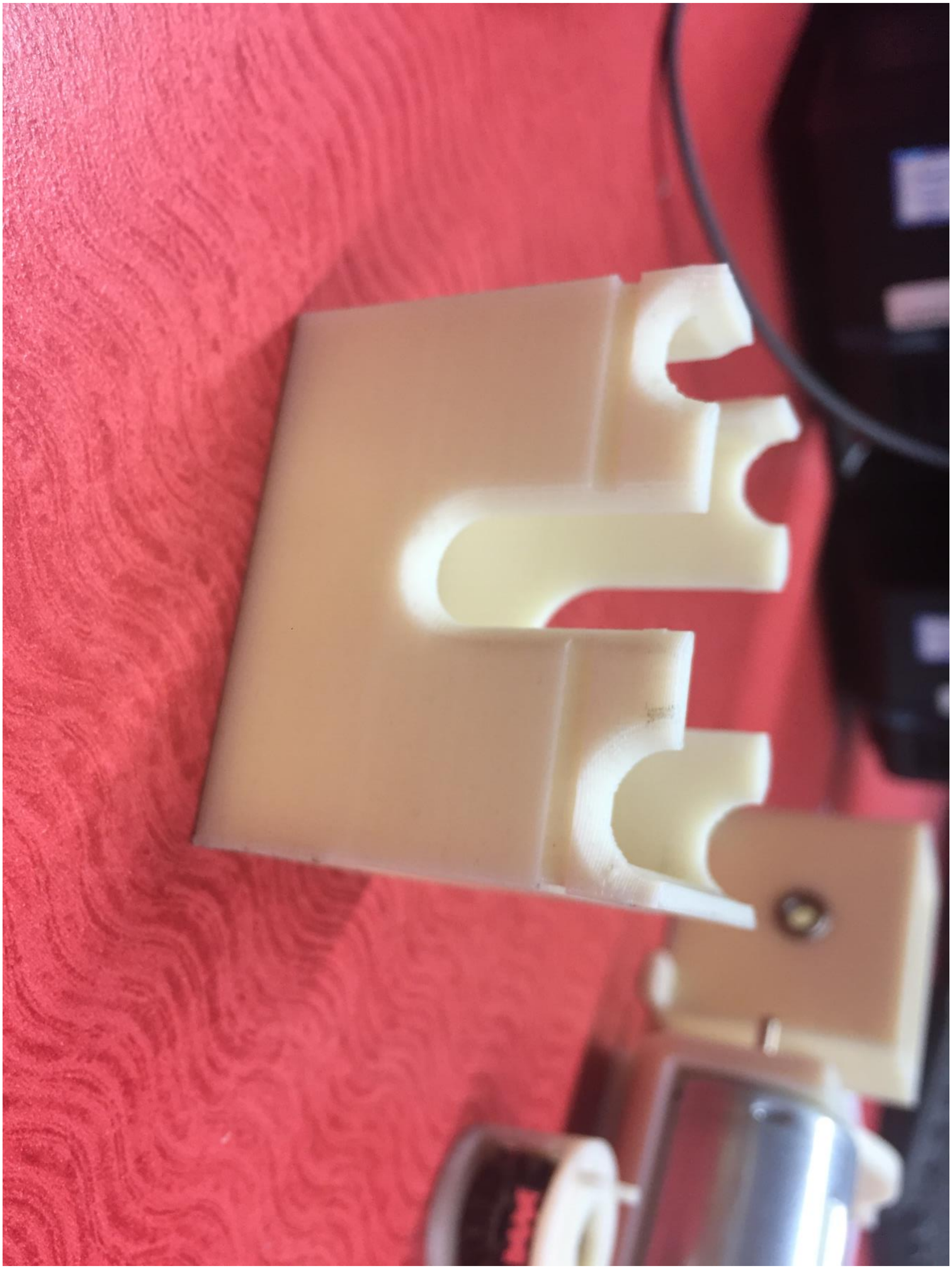


Appendix B.13









Video

https://www.youtube.com/watch?v=KwcTpkJE_IE&feature=youtu.be

Appendix C.1

	Part	Item #	Manufacturer	Cost ($)	Amount	Source	Dimensions	Status
	Motor	RS-540SH-6527	Machubi	4.97	1	Hobby King	36 x 58mm	Delivered
	Transmission Pinion	RRP0100	Robinson Racing	4.49	1	Amain Hobbies	9.5 x 13mm	Delivered
	Transmission Gear	KIM119	Kimbrough	5.99	1	Amain Hobbies	43 x 4mm	Delivered
	Differential Gears	RC4ZG0080	RC4WD	19.99	1	Amain Hobbies	13 x 43mm	Delivered
	Motor ESC	Xcar45A	HobbyKing	9.75	1	Hobby King	38x28x22mm	Delivered
	Rear Axles	hlna0807	Helion	12.99	2	Amain Hobbies	82 mm	Delivered
	Differential Gears	HLNA0815	Helion	7.99	4	Amain Hobbies		Delivered
	Axle Gears	hlna0816	Helion	8.99	4	Amain Hobbies		Delivered
	Drive Cups	hlna0819	Helion	12.99	4	Amain Hobbies	5 x 7 mm	Delivered
	C-clips	HLNA0848	Helion	3.49	4	Amain Hobbies	3mm	Delivered
	Servo	S3004	Futaba	13.99	1	RobotShop	41x20x36 mm	Delivered
	Wheels	TRA6873R	Traxxas	52.36	2	Hobby King	2	Delivered
Total				157.99	26			

Appendix D.1

Part Cost									
	Part	***Item #***	***Manufacturer***		***Cost ($)***	***Amount***	***Source***	***Dimension***	***Status***
	Motor	RS-540SH-6527	Machubi		4.97	1	Hobby King	36 x 58mm	Delivered
	Transmission Pinion	RRP0100	Robinson Racing		4.49	1	Amain Hobbies	9.5 x 13mm	Delivered
	Transmission Gear	KIM119	Kimbrough		5.99	1	Amain Hobbies	43 x 4mm	Delivered
	Differential Gears	RC4ZG0080	RC4WD		19.99	1	Amain Hobbies	13 x 43mm	Delivered
	Motor ESC	Xcar45A	HobbyKing		9.75	1	Hobby King	38x28x22m	Delivered
	Rear Axles	hlna0807	Helion		12.99	2	Amain Hobbies	82 mm	Delivered
	Differential Gears	HLNA0815	Helion		7.99	4	Amain Hobbies		Delivered
	Axle Gears	hlna0816	Helion		8.99	4	Amain Hobbies		Delivered
	Drive Cups	hlna0819	Helion		12.99	4	Amain Hobbies	5 x 7 mm	Delivered
	C-clips	HLNA0848	Helion		3.49	4	Amain Hobbies	3mm	Delivered
	Servo	S3004	Futaba		13.99	1	RobotShop	41x20x36 n	Delivered
	Wheels	TRA6873R	Traxxas		52.36	2	Hobby King		Delivered
BuildCost									
	Part	Material Cost ($)	Hours of Labor (@2$/hr)	Labor Cost ($)			Status		
	Transmission	22.17	0.2	0.4	22.77	1	Finished		
	Differential	21.69	0.2	0.4	22.29	1	Finished		
	Steering Assembly	6	0.2	0.4	6.6	1	Finished		
Total					209.65	24			

Appendix E.1

Displayed below is a Gantt chart that illustrates the expected timeline of the project development, and finalization.

Duration (Est.)	Duration (Act.)	Task	Task Number	10/11/2017	10/18/2017	10/25/2017	11/1/2017	11/8/2017	11/15/2017	11/22/2017	11/29/2017	12/6/2017	12/13/2017	12/20/2017	12/27/2017	1/3/2018	1/10/2018	1/17/2018	1/24/2018	1/31/2018	2/7/2018	2/14/2018	2/21/2018	2/28/2018	3/7/2018	3/14/2018	3/21/2018	3/28/2018	4/4/2018	4/11/2018	4/18/2018	4/25/2018	5/2/2018	5/9/2018	5/16/2018	5/23/2018	5/30/2018
26	92.2	Fall Quarter			"x" denotes a milestone																																
13	31	Design																																			
1	1	Allocation of Resources	SP-001																																		
1	1	Transmission Rough Design	SP-002																																		
1	2	Transmission Rough Design 2	SP-003																																		
1	1	Transmission Rough Design 3	SP-004																																		
1	2	Differential Rough Design 1	SP-005																																		
1	3	Differential Rough Design 2	SP-006																																		
1	2	Differential Rough Design 3	SP-007							x																											
1	0.5	Steering Assembly Rough Design 1	SP-008																																		
1	1	Steering Assembly Rough Design 2	SP-009																																		
1	2	Steering Assembly Rough Design 3	SP-010																																		
1	1.5	Design Decision Matrix	SP-011						x																												
1	4	Part Research	SP-012																																		
1	10	Part Measurement	SP-013																																		
13	61.2	Proposal																																			
1	1.5	Introduction	SP-014		x																																
1	1	Design & Anal	SP-015																																		
1	2	Methods & Construction	SP-016																																		
1	1.5	Testing	SP-017																																		
1	4	Budget/Schedule/Project Mangement	SP-018																																		
1	1.2	Discussion	SP-019																																		
1	1	Conclusion	SP-020																																		
1	0.5	Acknowledgements	SP-021																																		
1	25	Appendix A (Green Sheets)	SP-022								x																										
1	18	Appendix B (Drawings)	SP-023																																		
1	3	Appendix C (Parts List)	SP-024																																		
1	2	Appendix D (Budget)	SP-025																																		
1	0.5	Submission	SP-026									x																									
20	41	Winter Quarter																																			
20	41	Construction																																			
6	7.5	***Transmission***	SP-027																																		
1	2	Create Solid final Solid Works File	SP-028																																		
1	1	Purchase bearings for gears	SP-029																																		
1	1	Purchase screws for mounting	SP-030																																		
1	1	Ensure result fits dimensions	SP-031																																		
1	0.5	Purchase screws for motor	SP-032																																		
1	2	Machine bushing for gear	SP-033															x																			
14	33.5	***Differential***	SP-034																																		
1	3	Complete file for differential housing	SP-035																																		
1	3	Complete file for internal gear mounts	SP-036																																		
1	4	Print and submerge in lye bath	SP-037																																		
1	2	Redesign motor mounts to correct gear dimensior	SP-038																																		
1	3	Redesign differential housing to 2 parts	SP-039																																		
1	2	Redesign differential cover	SP-040																																		
1	6	Print and submerge in lye bath	SP-041																																		
1	1	Purchase 3 bearings for differential	SP-042																																		
1	1	Ream bearing holes to correct fit (Housing)	SP-043																																		
1	2	Ream bearing holes to correct fit (Gear Mounts)	SP-044																																		
1	2	Purchase bearing for transmission	SP-045																																		
1	3	Fix Differential Pinion to Transmission Gear	SP-046																																		
1	1	Assemble full differential	SP-047																																		
1	0.5	Add lubricant as necessary	SP-048																		x																
5	3	***Steering Mechanism***	SP-049																																		
1	1	Design cutout for best material utilization	SP-050																																		
1	0.5	Mill steering arms	SP-051																																		
1	0.5	Drill hole into servo	SP-052																																		
1	0.5	Drill holes into steering arms	SP-053																																		
1	0.5	Drill holes into steering rod	SP-054																				x														
17		Spring Quarter																																			
13		Testing																																			
4		***Speed Test***	SP-055																																		
1		Denote 30 feet markers on surface	SP-056																																		
1		Measure distance to full speed	SP-057																																		
1		Record time from A-B	SP-058																																		
1		Calculate Top Speed	SP-059																																		
3		***Turning Test***	SP-060																																		
1		Denote Starting point	SP-061																																		
1		Complete turn	SP-062																																		
1		Record end point	SP-063																																		
6		***Gear Loss Test***	SP-064																																		
1		Disassemble wheels	SP-065																																		
1		Measure Axle rpm	SP-066																																		
1		Compare to calculated value	SP-067																																		
1		Remove differential	SP-068																																		
1		Measure transmission RPM	SP-069																																		
1		Compare to calculated value	SP-070																																		
4		Final Report																																			
1		Consolidate Test Results	SP-071																																		
1		Record end result observations	SP-072																																		
1		Finalize Report	SP-073																																		
1		Compete in RC BAJA event	SP-074																																		
																																				x	

Appendix J.1

Douglas Erickson
1902 Yew Street, Ellensburg, Washington 98926
doug.erickson95@yahoo.com • 360-440-8505

EDUCATION

Bachelor of Science in Mechanical Engineering Tech June 2018
Central Washington University, Ellensburg, Washington

Associate of Arts
Edmonds Community College Edmonds, Washington June 2016

EXPERIENCE

Marina Attendant June 2016 - September 2017
Port of Edmonds, Edmonds, Washington

- Operated sling style 10,000 pound boat launch, assisted in 50 ton vessel transportation
- Pressure washed boats adhering to pertinent environmental regulations
- Assisted customers on fuel dock, in guest moorage facilities, and permanent tenants as needed
- Cleaned and maintained facilities and clerical work as needed

Sales Associate March 2016 - June 2016
The Home Depot, Poulsbo, Washington

- Provided fast, friendly service by actively seeking out customers to assess their needs and provide assistance
- Emphasized on the garden department and product knowledge
- Provided information on garden department product features and knowledge related items to sell an entire project

Line Cook April 2014 - December 2015
Mike's Four Star Barbecue, Port Gamble, Washington

- Prepared food in a timely manner for customers while maintaining quality. Multitasking in the kitchen became a necessary and required skill especially during busy situations. Many duties included overall maintenance of the store as well as taking orders from customers.
- Awarded Employee of the Month

SKILLS/QUALIFICATIONS

- CSWA Certified in SolidWorks
- Basic machine shop skills & CNC operation
- Photo/Video/Music editing ability
- Soft Skills: Reliable and Punctual
- Language: Conversant in German

References available upon request